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CACAO RESEARCH.

WHEN in 1930 the Cacao Research Scheme was launched at the Imperial College of Tropical Agriculture, it began to work upon a programme very carefully planned in advance. That programme took into account all the known facts about the cacao tree, and also the general principles established for other crops which might reasonably be expected, in the light of the known facts, to apply also to cacao although they had not been specifically proved to do so. It recognised that there were two main needs in the cacao-growing industry, namely, better trees and better methods of treating the trees already in cultivation. It frankly admitted that the amount of research necessary to meet either of those needs at all completely would occupy many years, but at the same time it held out the hope that some information of practical value would be forthcoming from quite early stages of the work, and that the output of information would be progressive.

The first and second Annual Reports* of the Scheme, issued within six months of each other, show with a wealth of scientific detail that even two years of research have brought both the objects appreciably nearer. It could not be expected in that period that any cut-and-dried new methods of increasing productiveness and decreasing costs would be evolved, but it was to be expected that new facts would be added to our knowledge of the crop, and that expectation has been realised.

In the matter of providing better trees, the programme stated that there were two parallel problems, namely, to find the best trees already in existence and to find the best method of propagating them so that their progeny should be uniform and of equally high capabilities. It did not consider desirable at the outset the breeding of new kinds, firstly because the process must be lengthy, and secondly because Nature had already conducted extensive breeding operations in Trinidad cacao plantations for some two hundred years and produced a collection of kinds unsurpassed in the world for variety. Instead, a genetic survey was recommended, to ascertain precisely what Nature had produced, and the

* First Annual Report on Cacao Research, 1931; issued December, 1932, price 1s. Second Annual Report on Cacao Research, 1932; issued June, 1933, price 5s. Copies of these Reports may be obtained on application to the Editor, *Tropical Agriculture*, Imperial College of Tropical Agriculture, Trinidad, B.W.I.

second report states that such a survey has now been completed. One whole crop season was spent in standardising methods of measurement, in order that figures collected should be reliable to a known degree of accuracy, and in the second year all the findings were checked in order to make sure that they held good under different weather conditions. Then nearly a thousand trees, scattered over eight stations in the three main cacao-growing areas of the Colony, were intensively measured, and reasons are given for maintaining that this sample is for all practical purposes truly representative of Trinidad cacao. For each tree the average dimensions of the pods were calculated, and the figures thus show approximately the lowest and the highest values which can be attained by Forastero cacao pods, as well as the dimensions which are in fact most commonly met with in the field. The calculation which will be of most direct interest to the planter is that of the number of pods which have to be broken to make one pound of dry cacao. Most commonly this is ten or eleven, but some trees consistently yield pods of which less than six make a pound of marketable beans, whilst other trees equally consistently bear pods of which well over twenty are required to give the same return.

Before a tree can be finally selected as suitable for propagation, its true yielding power must be determined, which is evidently the product of the number of pods produced in a year and the average value of each pod. Naturally in the time available it has not been possible to do that, except in the case of certain trees at River Estate of which pod production records have been kept for several years by the Trinidad Department of Agriculture. The immediate practical usefulness of the observations, however, is that they define the limits for selection and at the same time indicate how it may be most economically carried out. Since both pod number and pod value have to be taken into final account, it is easier and cheaper to select first on pod value and to restrict the more expensive observations of pod number to those trees which pass the first test.

Another interesting observation shows that selection by the methods described in the reports results further in the isolation of a better cacao. The commonest number of beans in a pod is 35, but there are rarely less than 30 or more than 40. It follows that the more productive pods yield more cacao, not so much because they have more beans, as because they have heavier beans. Heavier beans form a better grade of product, and in this respect quality can be improved without any sacrifice of yield.

With respect to the propagation of selected trees, it is reported that rooting has been effected by the use of both cuttings and layers, and the methods are described. Neither method is expected to pass immediately into plantation practice, but the true significance of these results is that they render possible a whole series of new experiments which previously could not be laid down. So long as the only practical method of vegetative propagation was by budding on seedling stocks, which are themselves mixed, no truly uniform trees could be grown for accurate comparisons of horticultural methods. Now that a scion can be made to form its own root system, the whole question of budding as contrasted with seedling propagation can be re-examined from a new angle. Selected trees can be propagated in experiment stations in a large number of different ways, and the types of trees resulting can be compared in behaviour with a definite standard of accuracy. Ultimately, the most desirable method for commercial use can be determined and standardised.

In the matter of increasing yields on established plantations of seedling trees, the programme held that much might be learned from a study of the shy bearers which form too large a proportion of the field population. The reports show that careful observations have been carried out on a number of trees for two years, to find out exactly when they set their crop, the relations between setting and flowering and change of leaf, and when and why young fruits shrivel up and fail to mature. The most striking item of new knowledge which has emerged from this part of the work is the discovery that a considerable proportion of the trees in a cacao field are self-incompatible, that is to say, they set no fruit, or very little, unless cross-pollinated from another tree. Similar behaviour is well-known in certain fruit trees of temperate regions, and its discovery in cacao is not surprising, but it is nevertheless a very important basis for further studies of fruitfulness. Self-incompatible trees evidently depend for their crop on the presence of some cross-pollinating agent, which has not yet been positively identified but evidently must be found and studied. Self-compatible trees, on the other hand, set crop with their own pollen, and in their case the size of the crop would appear to be more directly dependent on nutrition at the time when the young fruits are growing.

In nutrition the soil is obviously of primary importance, and there are important sections of both reports dealing with chemical investigations of cacao soils and the trees growing on them, and with the behaviour of cacao trees with special reference to their reactions to soil and meteorological conditions. Progress reports are given on a number of experiments designed to discover the inter-relationships between nitrogen, phosphorus and potassium, the three important nutrient elements which are concerned in growth and cropping. It is clear that these investigations cannot fail to give in due course results of the greatest practical usefulness.

Considerations of space, however, forbid discussion of all the important matters dealt with in these reports. Though they are loaded with tables of figures and with graphs, which may give them a somewhat formidable appearance, they

have been written in non-technical language throughout, and designed to appeal not only to the scientific officer who is concerned with local investigations in cacao culture, but also to the practical planter who has an intelligent interest in his crop. It is, after all, for the planter's ultimate benefit that all the researches have been planned, and it is in every way desirable that he should be well informed of their progress at every stage.

CULTIVATION AND DISEASES OF THE BANANA IN BRAZIL.

By C. W. Wardlaw and L. P. McGuire.

[*The following account of cultivation and diseases is based on investigations in the State of Sao Paulo, Brazil.*]

PART II.—DISEASES.

8. Bacterial Wilt Disease.

(1) *Introduction.*—A bacterial wilt disease of bananas, in which the pathogen has been recognised as *B. solanacearum* E. F. Sm., has already been described by Rorer (1) and Ashby (2) in Trinidad, B.W.I., and by Altson (3) in British Guiana. According to Rorer this disease occurred in epidemic form in Trinidad about the year 1890 and practically wiped out the Moko plantain, a useful and hardy variety which had been largely grown to provide shade for young cacao plants. A number of varieties of plantains and bananas, including the Canary or Cavendish variety, are susceptible to this disease, the high resistance of Gros Michel constituting a notable exception. With regard to the Cavendish, Ashby has noted that although this variety in Trinidad is subject to natural infection and can be successfully inoculated, it now seems to be rarely attacked.

During recent years a banana disease, now diagnosed as a bacterial wilt disease, has broken out in the Cavendish and Giant Fig varieties on plantations in the vicinity of Santos, Brazil.* The writers, on being called in to investigate, have found that the Brazilian outbreak presents a number of features which differ in some details from previous records. An account of the relevant investigations is set forth below.

(2) *Occurrence.*—The most important outbreak of the disease was observed on the Cavendish or Dwarf variety on "tabatinga" soil. The same disease was also found, to a less extent, on both the Cavendish and Giant Fig varieties on typical alluvial soils. As characteristic infections were noted on a number of different and widely separated properties, it seems probable that the disease enjoys a considerable distribution in Brazil.

(3) *External Symptoms.*—(*a*) *In the Cavendish Variety.*—The first indication of disease in the Cavendish variety is shown by the lower leaves which acquire a yellowish tinge not unlike that produced by drought effects. This is quickly followed by the appearance of similar colouration in all the other leaves, with perhaps the exception of the unrolled heart leaf. As the disease progresses the leaves acquire a more marked dingy yellow or whitish yellow colour and become dry and flaccid and readily droop in the heat. The leaf colouration tends to be evenly distributed over the lamina but is sometimes more intensive on one side of the mid-rib than on the other. From an early stage affected plants stand out conspicuously in the plantations in contrast to the normal green of healthy individuals (Fig. 14). The rapid breaking down of petioles, either at the junction with the pseudo-stem (trunk) or lamina as described elsewhere is not a conspicuous feature of the disease in Brazil. On the contrary the leaves showing colouration tend to persist in the normal position for a considerable time; finally, however, breaking down at the junction of the petiole and trunk takes place and the dead plant in time rots and falls to the ground.

A typical specimen showed the following leaf colouration and condition proceeding from the outermost (oldest) leaf inwards.

1 leaf (outermost). Completely brown and withered but with unbroken petiole.
1 leaf. Dull yellow, unbroken petiole.
1 leaf. Yellow-green.
3 leaves. Slightler yellowish green.
1 heart-leaf (rolled). Green, but with brown decayed patch inside.

Brown decayed areas in the rolled heart leaf were frequently found in diseased plants. They appear to be due to animal agencies, followed by bacterial activity, and are presumably referable to the debilitated condition of the leaf when the disease has reached an advanced stage.

Young sword suckers growing out from diseased plants show a noticeable and characteristic browning and shrivelling of the small leaf blades (Fig. 15). Splitting at the base of the pseudo-stem

(1) Rorer J. B.—A Bacterial Disease of Bananas and Plantains.—*Phytopath.* Vol. I, 1911; *Proc. Agr. Soc.* Trinidad and Tobago, No. 412, 1910.

(2) Ashby, S. F.—A Wilt Disease of Bananas.—*Tropical Agriculture*, p. 127, 1926; Bacterial Wilt Disease of Bananas.—*Kew Bull. Misc. Inf.* pp. 14-18, 1927; The Bacteria Wilt of Bananas and Plantains.—*Agric. Journ.*, British Guiana, I, pp. 218-220, 1928.

(3) Altson, R. A.—Memorandum on Panama Disease.—*Journ. Board of Agric.*, British Guiana, XX, 2, 1927.

*A Bacterial Wilt Disease, occurring in Argentina, the Chaco and possibly in Brazil, attributed to *B. musae* Zeman, was investigated by Zeman (†) in 1921.

† Zeman, V.—Bacteriosis del bananero (una nueva enfermedad).—*Revista de la Fac. de Agron. Universidad Nacional de la Plata*, XIV, No. 2, p. 17, 1921.

or trunk, characteristic of Panama Disease, was not observed. This is in keeping with the records of other investigators.

In some of the areas where the disease has been serious, soil conditions are such as to make for strong and rapid plant growth. As a rule no sign of infection appears until the plant is well grown. Affected plants are, therefore, usually of good stature and may be seen carrying bunches of fruit at different stages of maturity. Once the leaf symptoms become apparent, however, little or no further development of the bunch takes place, even in the case of a bunch which is half grown (half-full). The presence of the disease was found to inhibit further swelling and maturation of half-full fruit which was thus useless for reaping; in the case of the disease becoming apparent when fruit is well developed (say approximately "three-quarters-full") it may be possible to reap a marketable bunch (Fig. 15), though no data as to the behaviour of such bunches in transport and subsequent ripening are available.

In well developed stools the order of appearance of disease in the several constituent plants may sometimes be confusing. In the simplest case the oldest plant in the stool is the first to succumb to wilting; this is followed by the death of progressively younger plants as the disease becomes systemically distributed from parent to daughter suckers. It is only in such cases that young suckers are to be seen in a typically wilted condition with concomitant leaf discolouration. More complicated instances of infection within the stool are those where, of two plants of almost equal stature, one is obvioulsy diseased whilst the other is apparently healthy and supporting a good bunch. Again a youngish plant may show typical leaf discolouration whilst an older plant in the same stool may appear to be uninfected.

The explanation of these confusing manifestations of disease is probably to be sought in the source of infection. In the case of parent-to-daughter infections, the disease will normally progress systematically through the stool if the parent sucker or bit is uniformly infected throughout. It not frequently happens, however, that the disease is localised in one sector, in which case some irregularity in the transmission of infection to daughter suckers, arising at different points, may be expected. In other instances direct infection of one or more suckers by the pathogen in the soil, may account for the different conditions, wilted or healthy, of plants in the same stool. Where direct infection from the soil is involved, symptoms of disease are seldom seen in vigorously growing young plants. These continue to grow strongly until the drain on the plants' physiological resources reaches its maximum at the time of bunch formation, when as a rule the disease symptoms become apparent. In the same way the disease does not develop during the winter months when growth processes are almost at a standstill.

(*b*) *In the Giant Fig.*—Allowing for difference in habit, the external symptoms of disease in this variety are closely comparable with those exhibited by the Cavendish. Leaf discolouration tends to produce brighter hues, and a browning of the leaf margin, partly associated with leaf-spotting fungi, is not uncommon. Sword suckers show the characteristic browning and shrivelling of the small leaves. Some specimens showed a slight splitting at the base of the trunk but this was not comparable with that found in Panama Disease. In the Giant Fig the disease only appears at a late stage in the development of the plant and well grown daughter plants appear quite healthy.

(4) *Internal Symptoms.*—In the matter of internal symptoms the Brazilian bacterial disease differs to some extent from that described in Trinidad, B.W.I., where on cutting through a diseased pseudo-stem or trunk, practically all the vascular strands are found to be discoloured, the colour according to Rorer ranging from pale yellow to dark brown, or bluish black, with bacteria amply in evidence. This discolouration of the vascular strands can be easily traced back into the underground rhizome, as in Panama Disease, and according to the degree of infection, into the young suckers and buds. Again in severe infection the tissue of the petioles and pseudo-stems may be broken down into fairly large bacterial cavities, whilst soft patches may be also observed in the fleshy rhizome. In the Brazilian disease, on the other hand, the internal symptoms are very much less conspicuous. On cutting through the pseudo-stems yellow vascular discolouration is only to be seen in a few of the outermost leaf sheaths when the infection has reached an advanced stage; otherwise vascular discolouration was absent even in the trunk, close to the soil, the rhizome itself, and in the infected suckers. For example, in many plants showing five or six yellow-tinged leaves, the rhizome tissue appeared at a glance to be perfectly healthy, except for a pale yellow colour in the peripheral region of the stele; only in cases where defoliation was almost complete, was conspicuous "yellowing" at the periphery of the vascular ring noted. In the apex of such specimens the vascular strands had acquired an abnormal, pale-bluish and somewhat watery appearance. In such advanced specimens, softer darkish areas indicated the formation of bacterial cavities in the parenchymatous tissues as described by previous workers. Root bases with yellowish vascular tissues indicated the method of disease transmission from the soil to the rhizome.

The internal symptoms were closely comparable in both the Cavendish and Giant Fig varieties. In general it will be seen that the Brazilian disease is similar to that described in the West Indies, the difference in internal symptoms undoubtedly those of a vascular wilt disease being apparently one of degree rather than of kind, and presumably referable to particular local cultural conditions.

(5) *Isolation and Identification of the Causal Organism.*—Numerous routine isolations were carried out from time to time by the poured plate method, a synthetic dextrose-potato agar being used as culture medium. Uniform bacterial cultures were consistently isolated from discoloured vascular strands in the pseudo-stem, from typical yellow strands in the rhizome, from yellowish root bases and from diseased roots. Tissue, apparently unaffected, taken from both the apical and more basal regions of corms whose leaves definitely indicated disease, also consistently yielded bacterial cultures. This observation borne out by a considerable number of isolations, definitely indicates the presence of the organism in tissues even though no pronounced discolouration has been produced. Infected Cavendish material, from different sources, in the course of 53 isolations yielded bacterial colonies with one exception when a common saprophytic fungus (*Trichoderma* sp.) was obtained. Tissue from healthy plants on being subjected to the same treatment failed to produce bacterial colonies. From infected Giant Fig material, of 24 isolations, 23 yielded bacterial cultures only, while one, taken from a very advanced sucker infection, yielded a species of *Fusarium*. The latter, however, was not a member of the *Elegans* section to which the typical wilt-producing fungi, such as *Fusarium cubense* (the pathogen of Panama Disease) belong.

The majority of the bacterial colonies which developed in the poured plates showed a very considerable consistency in appearance. They developed quickly and had a characteristic wet, shiny, whitish appearance with a tendency to run. On standing a slight brownish colour developed. On transference to sterilised potato-blocks some but not all, of the cultures produced a greyish-white growth which later became chocolate-brown in colour and finally black. Under the circumstances of the investigation it was not possible to carry out the detailed cultural tests necessary to establish fully the identity of the organism.

When bacteria were injected into tomato plants, wilting took place accompanied by the formation of numerous small adventitious roots. The vascular tissues on dissection were found to contain numerous mobile bacteria. When re-isolation tests were made at points distant from the original inoculum, uniform cultures, corresponding to those applied, were obtained. The size and shape of the organism, its ability to live in the vascular tissues of Solanaceous plants, and the cultural characters already quoted, indicate that it may provisionally be referred to *Bacterium solanacearum* E. F. Sm., the causal agent in the West Indian bacterial wilt disease.

Again when bacterial cultures were injected by means of a hypodermic syringe or as needle smears into the petioles or leaf stalks of young banana plants, evidence was obtained in the course of 16 days of the ability of the organism to break down banana tissue and to live and travel in the vascular strands. A brown cavity 1 to 1.5 cms. in extent developed round the needle stab, and yellow vascular discolouration could be traced upwards over a distance of 5 cms. and downwards for about 3 cms. At the end of 26 days the extent of vascular discolouration was still more pronounced, 10 cms. or more being affected.

The concensus of evidence from various sources is thus indicative of the wilt disease caused by a strain of *B. solanacearum*, but cultural studies of the organism and further inoculation experiments on Solanaceous plants, and on bananas, during the season of active growth,* are required before a final expression of opinion can be given.

(6) *Microscopic Observations.*—Transverse and longitudinal sections through tissue traversed by yellow vascular strands were prepared and small bacteria in large numbers were observed in the cavities of the wood-vessels or conduits. Only in old infections, where secondary decay was setting in, were fungal hyphae occasionally noted in the vessels. Sections through the darkish parenchymatous areas already mentioned showed the individual ground cells, in proximity to diseased vascular strands, to be full of bacteria. Groups of such invaded cells, on further exploitation, break down and form the bacterial cavities which constitute a feature of this disease elsewhere.

The typical yellow discolouration of the vascular strands was found to be associated with the tannin ducts, and not with the wood vessels themselves.

Some points of interest were noted in sections through affected material taken near the apex of the sucker. Most of the wood vessels which did not contain bacteria showed a marked development of tyloses, presumably in response to bacterial activity lower down. The occlusion of the conduits by tyloses and the toxic influence of bacterial secretions probably account for the abnormal colouration and the dry, flaccid wilted condition usually found in the leaves of affected plants.

(7) *Nature and Extent of Spread.*—So far the disease has occurred chiefly on a recently planted "tabatinga" area. An adjacent zone of alluvial loam has carried bananas, with occasional replantings, for the last fourteen years. The "tabatinga", originally supporting virgin forest, was cleared and planted some three and a half years ago, the planting material having been obtained from the older cultivated areas. While individual plants had, from time to time, been observed in a sickly or diseased condition on the older plantings, the first serious outbreak of disease was noted in January, 1931, on the new

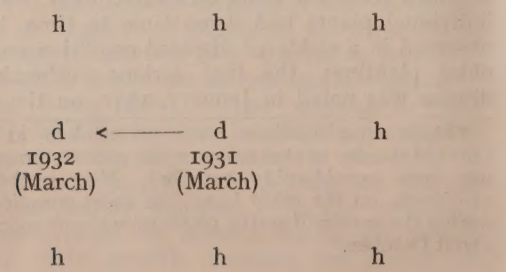
*These investigations were undertaken at the onset of the dry winter-season when growth processes are very considerably retarded. New outbreaks of disease, on the other hand, are most conspicuous during the season of active plant growth commencing about October.

areas. In some areas a yellowing of individual plants had attracted attention in November, 1930, but by January, 1931, it was seen that a considerable number of plants sometimes in conspicuous patches, were involved. In a two-acre patch, 70 per cent. of the plants were lost through disease in 1931. The diseased stools were removed in June, 1931, and supplies planted in November (Fig. 16). During 1931-32 only a slight marginal spread of the disease took place. On investigation, another diseased patch some 3 acres in extent yielded a similar history. From the information available, it appears that such areas became infected *en masse*, and that the disease did not spread from a central focus.

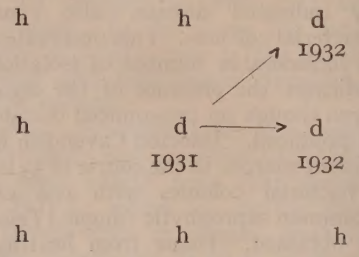
While the behaviour of diseased patches in 1931 on a certain property was undoubtedly alarming, the acreage so far affected is not great. The total loss included three areas of 2 to 3 acres, three areas of one acre, seven small patches and individual diseased stools scattered throughout the farm. The total area requiring replanting might be estimated at 20 acres. Altogether some 6,000 stools have already been treated for disease. As each stool would normally have yielded two bunches of fruit in 15 months the loss in fruit alone may readily be estimated. Fresh outbreaks in 1932, which are considerable, are not included in this estimate. A considerable amount of disease is also scattered through other farms but estimates are not yet available.

The disease may occur in isolated stools surrounded by healthy ones and slowly spread to one or at most two neighbouring stools in the course of a year. On the other hand, considerable areas may be involved at one time, the plants being killed out, in no definite succession, in the course of a few months.

Such variable distributions and manifestation of infection considerably complicate the interpretation of the problem. While the pathogen may be widely distributed in virgin soils and acquire virulence under certain planting conditions, much of the evidence is indicative of disease distribution resulting from the use of infected planting material—a difficulty not readily overcome in large scale operations. Further, once established, there is no doubt as to the infectious nature of the disease and its ability to spread in the soil. It seems probable that the rate of direct spread bears a relation to soil conditions. In some instances only one new case in proximity to a diseased stool may occur in the course of a year as indicated below.



The diagram shows an individual diseased stool (*d*) which had been destroyed and limed in March, 1931. On inspection in March, 1932, the disease was present in only one of the eight surrounding stools, the others being healthy (*h*) and bearing good bunches. Such instances are common, and it appears that the disease seldom spreads to more than two adjacent stools in the course of the year, the affected stools, as a rule, lying in the same direction. (*See* diagram below):



Examples of the spread of the disease to the second surrounding ring of stools during the course of a year have not been observed.

The rapid destruction of plants in areas of 2 to 3 acres is more difficult to follow. It may be that several pieces of infected planting material were distributed in such areas and that particular local conditions were conducive to rapid distribution of the pathogen through the soil and to its speedy attack on the host plant. Alternatively the pathogen may have been present in such areas under virgin soil conditions. It is worthy of note that, once the dimensions of such patches have been outlined, the marginal spread during the succeeding year has been slow, this being in conformity with the spread from individual stools already described.

Since it is known that the disease is caused by a soil bacterium, it follows that it may be spread by any agent which brings about the movement or transference of infected soil, *e.g.*, human or animal agents, cultural operations, surface water, &c. Disease may also be widely disseminated by the use of infected suckers or "bits".

(8) *Relation of Disease Incidence to Soil Type.*—So far the principal outbreaks of disease have occurred on "tabatinga" soil. At the same time, there is reason to believe that some bacterial disease must have been present in the neighbouring loamy areas for a number of years. Growth conditions on "tabatinga" are, however, peculiar. There the plants are growing in a layer of rich, humus-laden soil, overlying a wet, compact, bluish silt or clay. The strong and rapid growth characteristic of this area is to be attributed almost entirely to the relatively thin layer—6 to 10 inches of good top-soil. Roots which penetrate into the unoxidised clay below readily become diseased while a considerable amount of root disease is the rule even in the fertile top-soil. This is probably referable to the high humus content, and to the presence of

toxic substances in land recently reclaimed from swamp conditions. It has already been noted that the pathogenic bacterium is soil-borne that infection is transmitted to the rhizome or corm as a result of root disease, and that the causal agent has been isolated from young infected roots. The tendency of plants to become diseased is thus linked up with those soil conditions which are conducive to the production of extensive root rotting, or to the formation of a defective root system. Thus, the disease is not necessarily confined to soils of the "tabatinga" type, but may also occur on recently reclaimed acid sands, or on the stiffer hillside clays. On the other hand, the disease is of occasional occurrence only on the good alluvial loams, even in the case of properties 15 years old, and in one instance where an outbreak did occur, the disease is said to have largely disappeared under the influence of good cultural treatment. It may perhaps be anticipated, that, provided infected planting material is avoided, the disease will not cause much loss on the new alluvial loams which are being taken into cultivation, though the tendency of the disease to spread on humus-laden soils lying in proximity to the mangrove mud-flats must be regarded as serious, since some of the areas in question are at present highly productive.

(9) *Experimental Observations on Root Development.*—By way of investigating the relation between the physiological and chemical constitution of "tabatinga" soil and root development and disease, experiments were carried out along the following lines:—

(*a*) *First Series.*—A sample of typical humus-laden top-soil from a "tabatinga" area was mixed with an equal quantity of clean river sand, and placed in twelve large containers. These were then planted with uniform, washed, healthy suckers from which all the roots had been trimmed off. The plants were watered twice daily for 16 days with fresh river water during which new roots systems developed. Thereafter 8 of the plants were treated for the following 10 days with water in which a fair measure of "tabatinga" blue sub-soil had been allowed to soak. Further, in four of these tins the drainage holes were blocked up so as to produce a water-logging effect. The remaining four tins, the controls, were watered during this period with river water as before. Here it may be stated that it was anticipated that a normal healthy white root system would be found in the controls and that root discolouration or disease would have been induced, in different degrees, in the plants which had been treated with "tabatinga" water. This result, however, was not obtained. When the suckers were carefully uprooted and washed, they all showed root systems which were quite alike. On account of the sandy open texture of the soil a good root system with abundant laterals had developed from each sucker. While the main roots were still white and healthy, the laterals, even at this early stage, had lost the normal white colour which denotes health and had acquired the limp bluish appearance which precedes decay. Since this result was obtained in plants which had been growing in a mixture of top-soil and sand and watered with fresh river water only, it follows that the toxic properties which prepare the way for root disease are present in the top-soil as well as in the deeper layers. This is in keeping with field observations that a considerable amount of root disease is the rule in this soil type, even in healthy plants. Possibly if the experiment had been continued for a longer time the plants treated with "tabatinga" water might have shown an intensification of root discolouration.

(*b*) *Second Series.*—Representative samples of top-soil and sub-soil from a "tabatinga" area were collected and distributed in twelve containers as follows:—(1) 4, top-soil only; (2) 4, top-soil intimately mixed with subsoil in equal proportions; (3) 4, sub-soil only. The tins were planted with uniform, washed suckers from which all roots had been trimmed as above, and watered twice daily with fresh river water. On examination at the end of four weeks the plants set in top-soil had well-developed root systems, but, as described above, all the laterals had already commenced to turn blue. Those set in a mixture of top-soil and sub-soil had developed a very scanty root system and laterals, when present, were blue. Plants set in subsoil alone had been unable to develop roots. These results confirm field observations in that the compact, water-soaked, blue sub-soil is highly unfavourable to root formation. The experiment also shows that any cultural operations based on the mixing of top and sub-soil will, in the absence of thorough aeration and weathering, fail to achieve any satisfactory results in the promotion of root development.

(10) *Relation of B. solanacearum to Soil Conditions elsewhere.*—Rorer in 1911 stated that the disease in Trinidad, B.W.I., had been well controlled on small properties by sanitary measures based on the eradication of infected stools. The question of control has also been discussed by Ashby who points out that his proof of the identity of the banana wilt bacterium with *B. solanacearum* has made the findings regarding the latter applicable to the banana. This organism is widely distributed and has a considerable range of host plants including both wild and cultivated species. From evidence obtained in America and the Dutch East Indies, there is a strong probability that *B. solanacearum* is a normal inhabitant of some soils supporting either virgin or secondary bush. When the land is cleared and a susceptible crop planted, the disease makes its appearance—an explanation in keeping with some aspects of the outbreak in the Santos district. The organism tends to die out of soils under cultivation, a process which can be hastened by deep cultivation and thorough exposure of the soil during hot dry weather.

This depends on the fact that *B. solanacearum* produces neither protective spores nor capsules and is therefore not markedly resistant to desiccation.

In Sumatra the infection on tobacco is always more severe on the red lateritic soils and elsewhere on stiff soils, especially in wet weather, while in Florida it was found that the disease on Castor Oil was mostly restricted to soils deficient in lime. Such observations on the inter-relation between soil conditions and the parasitic activities of the bacterium have an immediate practical application to "tabatinga" soils.

(11) *Remedial Measures.*—It was suggested that treatment of bacterial wilt disease should be carried out along two lines:

(*a*) Eradication measures.

(*b*) Ameliorative measures.

(*a*) *Eradication of Infected Plants.*—The eradication of the under-ground portions of infected banana plants has always presented difficulties on account of the considerable cost involved in digging out the entire mat, the time required and the further difficulty of destroying the diseased material by burning or other methods. A further objection to uprooting stools in the case of soil-borne diseases lies in the fact that digging operations tend to disturb the surrounding soil with concomitant spread of the pathogen. During the last few years, however, Smith (1) has worked out a simple and cheap method of killing infected banana stools *in situ* by the use of heavy gas-oil which should be introduced as a standard procedure on properties where eradication of undesirable plants has to be effected. The method was tested with satisfactory results on one farm with the heavy gas-oil locally obtainable (Anglo Mexican), while some considerable time was also devoted to the instruction of operatives in the exact procedure to be followed.

The following treatment should be carefully applied to all infected plants:—

1. The larger trunks should be cut off transversely a few inches above soil level and pulled a little to one side.
2. *The dry trash, weeds and loose soil should then be carefully pulled aside with a hoe so as to expose as many of the small daughter suckers as possible. Careful preparation at this stage is of the utmost importance if good results are to be obtained.*
3. All young plants and exposed buds should be cut through.
4. The heavy gas-oil should then be slowly and carefully applied to the soil immediately surrounding the large trunks in such a way, that on seeping downwards, the oil will come into contact with all the underground "eyes" or growing points. Very little of the oil need be applied to the cut trunks to effect killing.
5. The trunks which have previously been cut down, should be drawn back over the treated stool and chopped up. Only in the case of very advanced infections need oil be applied to the chopped trunks.
6. Heavy gas-oil should be applied at the rate of ½ to ¾ gallon per large stool, or less, at the discretion of the overseer, in the light of local soil conditions. A small watering-can with a fine rose was found useful for the slow and localised sprinkling of the oil.
7. Treated stools should be suitably marked and inspected after a few weeks. Any young plants which have escaped destruction and commenced to grow can readily be uprooted by hand.

The gas-oil treatment which depends on the quick killing and rotting of tissue, is not only very effective, but can be carried out at reasonable cost by a small labour gang. The rapid rotting of banana suckers and "bits" by the oil was demonstrated in a number of experiments, the killing of the young "eyes"—an important part of the treatment—depending apparently on the rapid absorption of the oil by the papery scales and old leaf bases. The use of oil does not preclude replanting after a short lapse of time.

Elsewhere soil borne diseases of this type have been treated by fixing a quarantine area round each infected plant, the surrounding healthy plants being eradicated at the same time as the central diseased one. In view of the slow spread of the disease from year to year as described in previous sections, the isolation of individual diseased areas by a 5 or 9-root quarantine measure does not seem a necessary precaution or one that can, in actual practice, be made thoroughly effective. An inspection service, however, should be instituted so that diseased plants can be recognised in the earliest stages and eradication carried out at once. The programme outlined above, should, in the present early stage of the disease, make it possible to effect a thorough eradication of all infected material. As a rider to these observations the greatest care should be exercised in the choice of planting materials for new areas, the "bits", for preference, being taken from good loamy areas where disease has not appeared.

(*b*) *Ameliorative Measures.*—In order to avoid further loss through the disuse of areas on which the disease has appeared, some attempt must be made to effect amelioration of soil conditions to permit of successful replanting. The following suggestions, while they refer particularly to certain "tabatinga" areas, where the disease is worst, may also be found applicable, with suitable modification, elsewhere. It has been noted in earlier sections that root disease is the primary source of infection of the underground rhizome or corm. Ameliorative measures will depend therefore, on securing improved rooting conditions. On replanting individual diseased

(1) Smith, F. E. V.—*Tropical Agriculture*, IX, 3, pp. 83-86, 1932.

areas or the larger diseased patches, a change from the usual procedure should be adopted, the usual small planting hole, 15″ × 15″ (approximately) being inadequate.

The following preparations for replanting should be carried out provided that seasonal conditions, labour supply and the general economic situation permit.

1. Holes for replanting should be dug 2½ to 3 feet in diameter and about 24 inches deep.
2. The excavated soil should be thrown out round the hole and broken and spread so as to permit of maximum exposure to the air.
3. Some admixture of the top and sub-soil should be effected and lime sprinkled on so as to make the maximum contact with the soil. (In the previous treatment of the disease, considerable quantities of lime were applied as mounds over the diseased stools to effect killing. As lime mainly affects the soil particles where actual contact is made, a small quantity adequately incorporated and distributed in the soil is much more effective than a much larger quantity placed on the surface.)
4. Replanting should be delayed for several weeks to permit of exposure and soil oxidation. The relation of such operations to the eradication of the pathogenic bacterium have already been discussed.
5. On replanting, the exposed soil should be scraped together and used to fill the hole round the " bit ".
6. It is not suggested that these operations (which will be considerably more expensive than the usual preparation, though definitely not uneconomic), should be used wherever planting operations are being carried out. They should be given a trial on those diseased patches which are regarded as being too valuable to be allowed to go out of cultivation.
7. In the case of certain farms on low situations, particular care should be given to the upkeep of drainage. It is also possible that, in view of the exceedingly compact nature of the blue clay subsoil, some improvement could be effected by increasing the number of subsidiary drains. The general main drainage system in operation is good, provided all the channels are kept open, but the actual *local* drainage, if increased with discretion, would in time, remove the excess of subsoil water and thereby considerably improve soil aeration.

In view of the need for effecting soil amelioration, a number of experiments have been commenced, in which top-soil and subsoil have been mixed with, and without, the addition of limestone and spread out for exposure. Even in a few weeks the improvement in texture, particularly in the case of those to which lime had been added, was very marked indeed, indicating the probable success of the cultural treatments outlined above, when carried out at a favourable season.

8. If the general distribution of farm activities permit, the preparation of holes for replanting (as outlined above) should be undertaken at the beginning of the winter or dry season. The soil which is broken up and spread out will thus be subjected to the maximum desiccation, thereby effecting a greater destruction of the unprotected pathogenic bacteria, a process which may also be furthered by exposure to the night cold during what is virtually a fallow period. The soil should thus be in good condition for replanting at the commencement of the following growing season.

A common and successful method of combating soil-borne diseases of this type consists in the utilisation of immune or highly resistant varieties. In the West Indies, the following varieties are known to be susceptible to bacterial wilt disease:—

Moko or Bluggoe Plantain.
Cavendish or Dwarf Banana.
Giant Fig.
Red Banana.

The Gros Michel appears to possess high resistance in the field although disease effects can be produced by inoculation. The Sucrier (Lady's Finger) can also be successfully inoculated but the available reports are not explicit as to its susceptibility under field conditions.

(*To be continued.*)

DWARF COCONUT PALM.

An account is given in the *Malayan Agricultural Journal* (Vol. XXI, No. 4) of investigations carried out on estates and on the Government Coconut Experiment Station, Klang, on the growth and yield of dwarf palms and on the quality of the copra they produce. It is shown that these palms appear to be more sensitive to unfavourable conditions than tall palms and that they respond quickly to improvement or deterioration in conditions. At an early age very remarkable yields are obtainable if conditions are favourable but in most instances yields are only fair or poor because conditions do not fulfil the exacting requirements of the dwarf palm. Free water movement in the soil is essential for good growth. The best results have been obtained on very heavy clays. Even if special care is taken in the manufacture of copra from dwarf palms, none of the varieties yield a product equal in quality to that obtainable from tall palms growing under similar conditions. The best dwarf palm copra is said to be obtainable from the green variety and the worst from the red variety.

THE CAVENDISH GROUP OF BANANA VARIETIES WITH SPECIAL REFERENCE TO LACATAN.

By E. E. Cheesman, C. W. Wardlaw and G. L. Spencer.

Introduction.

For some time past tall banana varieties labelled *Lacatan, Bumulan, Martaban, Giant Fig* and *Masak Hijau* have been grown in close proximity in the Imperial College variety collection with a view to determining their botanical affinities. Hitherto these varieties, known to other observers from plants grown under different conditions of soil and climate, have been generally regarded as quite distinct, although it has been appreciated that they all possess certain features in common. When grown side by side in pairs in special comparison plots, however, under close observation at all stages, they proved quite indistinguishable, and careful search failed to reveal a single definite criterion by which one could be separated from another. It is a rational inference from such observations that these so-called " varieties " are, in point of fact, one and the same clone, and in support of that hypothesis evidence will be adduced both from the appearance and behaviour of the plants in the field and from the behaviour of comparable bunches of their fruit when stored and ripened under controlled conditions of temperature and humidity. The best known of the various names is *Lacatan*, and we shall in future adopt that designation of the variety.

Simultaneously, the same and parallel observations have led us to the further conclusion that the tall variety *Lacatan* is closely related to the *Dwarf Banana*, usually referred botanically to *Musa Cavendishii*, and cultivated in nearly all tropical and many sub-tropical countries under such names as *Chinese, Cavendish, Canary, Governor, Ananica*, &c. Detailed evidence in favour of this hypothesis will also be adduced, but it may be stated at the outset that a connecting link between forms so apparently dissimilar at first sight as *Lacatan* and the *Dwarf* exists in the group of varieties of intermediate stature recently described as " Mutant Types of the Dwarf Banana " (2), including *Congo, Grande naine, Giant Governor* and others. For the whole assemblage of dwarf, semi-tall and tall forms we suggest that " the Cavendish Group " is a convenient and appropriate designation.

Identification of Lacatan, &c.

Lacatan exists in the variety plots under no less than eight different labels altogether, representing eight distinct collections from six different countries. Since identity was first suspected the " varieties " have been grown literally side by side in pairs, the comparison plots being so arranged that the conditions of growth were as nearly uniform as possible, and the stools being under continuous observation from planting to fruiting. Conditions in general could not be described as ideal for banana growing, but probably represented average conditions under which the fruit is grown outside the big producing areas ; in short the stools were healthy but not luxuriant, and seven and eight-hand bunches were the commonest.

Points to which particular attention was paid in comparison were : Height, rate of growth, amount of tillering, colour and markings of pseudostems at comparable ages, character of petiole wings, colour of midribs, colour and shape of bracts and nature of their overlap in the male bud, characters of female flowers, characters of male flowers, general form of bunches, age for age, hairiness of bunch stem and finger stalks, persistence of stigmas, shape of full fruit. Experience of other varieties has shown that one or more of these characters, and usually several, will provide criteria by which types really distinct can be separated. In one of the most difficult cases, namely, the separation of Lacatan from Gros Michel, at least three of them are operative. Yet between these " varieties " not a single point of distinction could be found.

To throw further light on the question of identity, bunches approximating closely in age were harvested from adjacent rows, or in cases where " varieties " had been interplanted even from the same row, and held in the course of two storage trials at 56°F. and 58°F. respectively. After 16 to 18 days in cold storage these bunches were ripened at 70°F., a relative humidity of approximately 85 per cent. being maintained throughout.

Apart from slight variations in the rate of ripening, which are to be expected in individual samples, the bunches showed a number of features in common, viz. :

1. They were comparable in general shape and symmetry, though all had the appearance of fruit grown under rather unfavourable soil conditions.

2. All possessed a rather thin and weak main-stalk and showed a marked tendency for individual finger-stalks to suffer from mechanical injury and subsequent *Gloeosporium* infections.

3. The tendency of the fingers of the topmost hands to fall apart in an irregular manner, when the bunches were suspended with the proximal hand uppermost, was common to all.

4. All showed slow or delayed ripening of the rather thin fruit.

5. All fruits which ripened developed a clear, pale yellow colour ; with the onset of late maturity a characteristic freckling was the rule, quite similar in the several " varieties ".

6. The smaller and more immature fruits of the lowermost hands failed to ripen and developed a pasty discolouration and russetting which was comparable throughout. This effect was similar to that observed in the storage of immature bunches of the (Dwarf) Cavendish.

7. While an attractive yellow colour developed in fruit originally stored at 58°F. and 56°F., bunches of the several "varieties" held at the latter temperature all showed a slight sootiness, particularly on the lower sides and round the finger-tips, which might be regarded as a mild chill effect.

8. A characteristic discolouration and dehydration effect induced in the slender finger-stalks was identical throughout.

Thus from the cumulative field and storage data available, the general consensus of evidence all points to the conclusion that the several so-called varieties are in fact identical, and so far no evidence has come to light which may be regarded as contrary to that view. Identity of origin is practically impossible to prove in a positive sense, but identity of constitution may be assumed as a working hypothesis.

Distribution of Lacatan.

Lacatan is a name well-known in the Philippines and is mentioned by Fawcett (4) and Mendiola (8). A description of the variety has been given by Teodoro (11). It has attracted serious attention as a possible substitute for Gros Michel in commercial cultivation on account of its resistance to Panama Disease, and has been the subject of investigations at the Low Temperature Station here (12). The stock actually under this label in our collection of varieties was obtained from the Trinidad Department of Agriculture, and apparently came from the Philippines *via* Costa Rica.

Bumulan was obtained from the Director of Agriculture in Surinam. It apparently originated likewise in the Philippines and reached Surinam *via* Washington. The possibility of its identity with Giant Fig has been suggested by Ashby in 1924 (1) and by Del Canizo and Rodriguez Sardina (3).

Giant Fig is a West Indian name, and our material came from Grenada, where attention was drawn to the variety about 1923 on account of its resistance to Panama Disease. The same variety was found about the same time to occur in St. Lucia under the name of *Bout Rong*, a patois rendering of "bout rond", referring to the round end, or apex, of the fruit. For some time collections from St. Lucia and Grenada were kept distinct in our plots, but the identity of the two was accepted several years ago.

Martaban was the label on a collection from British Guiana. Now Martaban is a variety well-known in India, being mentioned by Firminger (5) among other writers, and there is a record by J. Jones in the Report on the Botanic Station, Dominica, for 1902-03 of this variety having been received from Kew at some time during the previous four years. There is likewise a record of suckers of the introductions from Kew being distributed from Dominica to neighbouring Colonies, which accounts for the presence of the name in British Guiana. If it could be taken as certain that the material we received was true to label, not only would Giant Fig be identified with the Martaban of India but its probable origin in the West Indies would be indicated. Unfortunately we do not feel justified in basing synonymy on the assumption that a variety has remained true to label for thirty years whilst not under any particularly close observation, and the identity of the true Martaban of India with Lacatan remains an interesting question for settlement later, when we may be able to compare a fresh collection from India with our stock.

Masak Hijau is a Malay name meaning "ripe green", an allusion to the yellow-green colour to which the fruit ripens at tropical air temperatures. It is listed by Hale (6) and Milsum (9) and briefly described by Howes (7). Our material was collected in Malaya by F. N. Howes and received here *via* Kew. It is particularly interesting to be able to identify this collection with Lacatan, because the identification illustrates the complexity of banana nomenclature and the value of varietal studies.

Sands (10) gives *Pisang Embun Lumut* as an alternative name for Pisang Masak Hijau in Malaya, and notes that this is sometimes incorrectly referred to as *Pisang Embun*, though the true Embun is Gros Michel. *Pisang Ambon Loemoet* of Java is obviously the same name, so that it would appear that in Java as well as Malaya both Gros Michel (Ambon) and Lacatan (Ambon Loemoet) occur and are apt to be confused. The confusion is natural enough since the varieties are very much alike in habit and morphology, though quite different in physiology. In the field they can often be distinguished only with difficulty by experienced observers, and confusion has certainly arisen in the New World for two of our own eight collections of Lacatan were originally received as Gros Michel.

Now from the notes on bananas in Eastern countries given by Howes (7) it is clear that in Ceylon, in Burma and in Siam there are parallel cases of pairs of varieties, closely similar in field characters but differing in the ripening of the fruit. In each case one of the pair ripens yellow and is thought to be Gros Michel or something very closely allied. In each case also the other member is described as green or greenish-yellow when ripe. It appears most probable that the latter is in each of these countries the same as in Malaya, that is to say Lacatan. If it is not so, the coincidence is curious, and if it is so then Lacatan is one of the most widely distributed varieties in cultivation.

It may be added that the *Mestica* of Brazil, now shipped in considerable quantities to European markets, is also apparently to be identified with Lacatan, though we have not yet grown it in our comparison plots.

Relationship to the Dwarf Cavendish.

It will be apparent from what has been stated above that Lacatan in the field shows a remarkably close resemblance to Gros Michel, and on that account it may seem strange that we should group

it genetically with a banana that at first sight is notably distinct. An observer guided by morphological similarities alone would indeed be almost certain to regard Lacatan as a very near relative of Gros Michel, yet the physiological differences between these two are many and are even more striking when fully appreciated than the superficial resemblances. Furthermore, the physiological characteristics of Lacatan seem in every case to be identical with those of the Dwarf banana. It is primarily on a physiological basis therefore that we suggest close relationship between those two, but as will appear, their morphological characters, properly regarded, are likewise consistent with our hypothesis.

Of physiological characters to be observed in the field, the high resistance of both to Panama disease is notable, and gives both much of their economic importance. On the other hand, in Trinidad both are subject in the field to Black-tip disease (*Helminthosporium torulosum*) the symptoms in both being identical (13) whilst in Brazil both (taking Mestica as Lacatan) seem equally subject to field attacks of Moko disease (*Bacterium solanacearum*) and to a mild type of infectious chlorosis (14).

Fruit bunches which ripen at tropical air temperatures develop in both cases the same greenish-yellow colour, in marked contrast to the golden yellow of Gros Michel, and bunches under controlled conditions in cold storage and ripening rooms show many essential similarities in their behaviour. Notable features of both in storage are the slow ripening of immature bunches, freckling on ripening, susceptibility to bruising and to *Gloeosporium* infection, and the development of a pasty or russet colouring by immature fruits in the ripening room.

Morphological similarities are discussed under the next heading.

The Connecting Link.

In a recent article (2) evidence was summarised for the view that the Dwarf banana has more than once in its history thrown bud sports, which in the most interesting cases are intermediate in stature between dwarf and tall varieties and may be called semi-tall. It is not yet known how many of these intermediate forms there are, but there are certainly two and probably more. One form or group of forms seems to differ from the ordinary Dwarf in little or nothing beyond stature and vigour. Another differs not only in stature but in shedding all its male flowers with their subtending bracts soon after they have opened, leaving the rachis clean and naked. A probable third, still under observation, seems to vary in the degree to which it holds or sheds its bracts according to age of bunch and environmental conditions, and provides a link between the fully persistent and fully deciduous bract habits. The fruit of all these varieties in storage exhibits all the features described above as characteristic of the Dwarf and of Lacatan.

For the purposes of the present discussion, interest centres on the type or types with naked rachis, represented in our collection, for example, by *Congo*. It was pointed out in the article cited how profoundly the shedding of the bracts modifies the whole appearance of the plant in the field, yet it can after all only be regarded as a minor genetic character. Now the variety Congo was provisionally grouped by one of us with Lacatan long before its connection with *M. Cavendishii* was suspected, and if the reasons previously advanced for regarding Congo as derived from, or at least closely related to, *M. Cavendishii* are valid, there can be no logical reason for excluding from the same genetic group a variety which essentially differs from Congo only in being considerably taller.

Carefully ignoring the conspicuous but unessential differences in stature and bract-shedding we have compared the dwarf, semi-tall and tall varieties concerned in the respects enumerated above. We can find no criterion of distinction in colour or markings of pseudostems, petiole wings, or floral characters. The range of variation with environment in bunch habit is similar for all, and the same holds for fruit shape. Thus the morphological features, taken as a whole, show nothing to contradict the hypothesis of relationship based in the first place on physiological characters.

Sterility of the Cavendish Group.

Yet another common feature which is of genetic significance is the completeness of sterility throughout the series. In view of their economic importance all the "varieties" mentioned above have had a prominent place in our breeding programme, and now that we feel justified in pooling the results from the different labels the evidence is a weighty addition to that advanced above.

Our records show that between September, 1927, and January, 1932, 137 bunches of the dwarf, 111 bunches of the semi-tall, and 371 bunches of the tall forms were harvested after pollination with six different male parents. Seeds were recorded in four bunches of Lacatan, under conditions which gave rise to grave suspicion that Gros Michel bunches had been pollinated by mistake. Seeds were also found in two bunches of Congo under conditions of some doubt. None of the seeds germinated, and the rest of the bunches, 613 out of 619, were completely seedless. Later trials with other male parents have similarly failed. Throughout the period mentioned, the same pollinators were obtaining seeds freely from other clones. Gros Michel, for example, gave seeds in 28 bunches out of 125 pollinated by the same parents, and more fertile clones yielded seeds in the majority of bunches harvested. It is therefore most unlikely that technique was at fault, and the sterility of the Cavendish group, at least under our conditions, is beyond reasonable question.

Summary.

From observations carried out over several years and embracing field comparisons, fruit storage trials, and attempts to produce seed, it may fairly be concluded :—

1. That Lacatan, Bumulan, Giant Fig and Masak Hijau are one and the same variety, best known as Lacatan.

2. That Lacatan is closely related both to the dwarf banana, usually called *M. Cavendishii* and to certain varieties of intermediate stature, including Congo, the whole assemblage of dwarf, semi-tall and tall forms forming one genetic group which may appropriately be termed the Cavendish group.

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WORLD POULTRY CONGRESS.

The fifth World Poultry Congress and World Exhibition will be held in Rome from the 6th to 15th September, under the High Patronage of His Majesty the King of Italy. Details regarding the congress may be obtained from the General Secretary, Ministry of Agriculture and Forestry, *via* XX Settembre, No. 18, Rome, Italy.

MAIZE STRIPE DISEASE.

In March, 1933, plants of the great millet (*Andropogon sorghum,* Brot.) growing on the College farm were found showing leaf-stripe symptoms very similar in appearance to those of Maize Stripe disease described in the number of this Journal for May, 1933 (1). Inoculation experiments were carried out and Maize Stripe disease was successfully transmitted from maize to the great millet by means of the Fulgorid leaf-hopper, *Peregrinus maidis,* Ashm. Leaf-stripe symptoms comparable with those found on the millet in the field were produced, and it is clear that the diseases on these two plants are identical.

Stripe disease has not yet been recorded from plants other than maize and the great millet, but *Peregrinus maidis* has been found on various other members of the Gramineae. Ogilvie (3) in Bermuda found the insect on sugar-cane, sorghums, *Eleusine indica,* Gaertn. and *Panicum dichotomiflorum,* Michx., while Cotton (2) found it on sugar-cane in Porto Rico. It has not been found on sugar-cane in Trinidad. The insect is of widespread occurrence on maize and has been recorded from Trinidad, Barbados, Cuba, Porto Rico, Bermuda, Hawaii, and Tanganyika, and probably occurs in many other places.

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R. E. D. B.

COMBINED INSECTICIDE AND FUNGICIDE.

The combined insecticide and fungicide described by Dr. H. R. Briton-Jones in the March issue of *Tropical Agriculture* is now being manufactured by Messrs. Trinidad Leaseholds, Ltd., Pointe-à-Pierre, Trinidad, B.W.I. This product which for the time being is sold under the name "Sulphemulsol", is being made on a considerable scale in a specially built plant and has been shipped to various parts of the world for use on many different types of cultivation. Supplies are obtainable from Pointe-à-Pierre in free steel drums of 60 gallons capacity at 1*s.* 3*d.* per gallon, or in cases of eight gallons at 13*s.* 1*d.* per case, which includes the cost of the containers both f.o.b. Trinidad. Enquiries in connection with the supply of "Sulphemulsol" should be sent direct to Messrs. Trinidad Leaseholds, Ltd., Trinidad, B.W.I.

ENTOMOLOGICAL CONTRIBUTIONS TO THE STUDY OF THE SUGAR-CANE FROGHOPPER.

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1.—The Study of Biotic Factors of Control.

(*a*) *Egg Parasites.*

Prior to the establishment of the Division of Entomology as a branch of the Sugar-Cane Investigation, two insects parasitising the egg of *Tomaspis saccharina* were recognised, *viz.*, the Vermilion Parasite (*Oligosita girault*i Crawford) and *Paraphelinus tomaspidis* Howard (11). The methods adopted in the early years of froghopper research left some doubt as to what extent these parasites were capable of controlling their host and there was also little information as to the range of hosts which they might attack. Experience showed that the parasites did not seem to increase in the cane fields to such an extent as to control the froghopper, and detailed studies were accordingly made of froghopper eggs taken from the field, in order to determine what insects occurred in them as parasites and under what conditions. An account of the first year's work on this problem has already appeared (9) and considerable information as to the activity of egg parasites has now been obtained.

The egg parasite most in evidence throughout the study has been *Anagrus urichi* Pickles (Hymenoptera, Mymaridae), a species unknown to science prior to the commencement of these studies (*loc. cit*). While other Hymenopterous parasites occasionally attack the eggs of *T. saccharina*, this is the only one of regular occurrence. One of the minor parasites found in froghopper eggs was *Abbella tomaspidis* Pickles (*loc. cit*). This was found in 1932 parasitising the eggs of an unknown Homopterous insect (Jassid?), which is probably a more normal host. *Oligosita girault*i has been encountered in froghopper eggs on some two or three occasions only and at the present time at any rate, appears to be only an occasional parasite of *T. saccharina* (*vide* Kershaw, 4). One egg of *T. pubescens* from the Caura Valley was also found parasitised by this insect. No other hosts of *O. girault*i have been found. A soil sample taken during the year from a forest habitat near Moruga was found to contain eggs of both *T. saccharina* and *T. pubescens*. Some eggs of the former species were parasitised by *A. urichi*, while one egg of the latter was attacked by a related, though distinct species of *Anagrus*. The evidence obtained thus seems to indicate a considerable degree of specificity in the attacks of *A. urichi*, since it has been found only in the one host species, and in that host it occurs commonly.

The numerical records of the incidence of *Anagrus urichi* now extend over more than two years for a number of localities, and are of some interest as illustrating the effect of dry season conditions on the abundance of the parasite. The complete data for the incidence of the egg parasite on sugar-cane estates during the years 1930, 1931 and 1932 are given in Table I. These figures differ in many instances from those previously given in the monthly progress reports of the Sugar-Cane Investigation Committee, where the parasitism rate is quoted as the number of parasitised eggs per hundred eggs otherwise viable. In the present instance, the figures represent the number of parasitised eggs per hundred unhatched eggs, without further distinction.

Scrutiny of the figures shows that climate has an important bearing on parasite incidence. In all the years reviewed, there is practically a complete cessation of parasite activity during the dry months of the year (Fig. 1). Further, the incidence is particularly irregular during the year 1930, which was characterised by a very dry wet-season. The year 1931 opened with a very severe and prolonged dry-season, which was followed by heavy precipitation on the opening of the rains, but the adverse effect of such an extremely dry season on parasite incidence is shown by the fact that the parasite does not become general in distribution until October and November. After the wet dry-season of 1932, however, although parasites could not be found during February, March and April, they became active generally by May and June.

It may therefore be concluded that dry weather is definitely unfavourable to the propagation of *Anagrus urichi* and that a prolonged dry-season may reduce its numbers so severely that it may be practically non-existent for several months after. But, Williams (*loc. cit*) shows that a prolonged and severe dry-season appears to be the forerunner of a very severe froghopper attack, and all recent experience appears to confirm this conclusion fully. It therefore follows that an egg parasite of physiological relations such as are possessed by this insect would be most scarce at the time when its presence is most urgently required in quantity.

As will appear later, a high mortality of the eggs of *Tomaspis saccharina* occurs during the dry-season, and to a smaller degree, throughout the year. Thompson (10) shows that destruction of the hosts of a parasitic insect, without a corresponding destruction of the parasites, slightly increases the rapidity of the reduction of host numbers. Reduction of hosts and of parasites in equal proportions should theoretically leave the parasite-host ratio unchanged. Marked reduction of the ratio of parasitism, such as was

Table I.

Monthly incidence of *Anagrus urichi* on certain sugar-cane estates, expressed as the number of parasitised eggs per hundred.

Estate.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1930.												
Orange Grove ..	..	..	0	0	0	0	0	0	0	2.9	0	0
Caroni ..	..	..	0	2.5	0	0	0	0	0	5.0	0.6	1.8
Woodford Lodge ..	..	..	0	0	0	33.0	0	11.0	0	0	1.4	0
Waterloo ..	..	..	0	0	0	0	0	3.4	0	0	0	0
Brechin Castle ..	..	..	0	0	0	0	0	1.2	0	0	0	0
Esperanza ..	..	..	..	..	..	..	0	0	1.0	0	5.0	0
Ste. Madeleine ..	..	..	0	0.7	0	0	0	0	0	0	0	0
1931.												
Orange Grove ..	0	0	0	0	0	0	0	0	0	0	7.0	0
Caroni ..	0.4	3.8	0	0	0	0	0	1.8	1.0	1.7	2.8	0.8
Woodford Lodge ..	0	0	0	0	0	0	0.8	0	0	13.0	0.6	0
Waterloo ..	2.8	0	0	0	0	0	0.1	0	0.1	1.2	1.6	1.0
Brechin Castle ..	0	0	0	0	0	0	0	0	0	0	0.7	0
Esperanza ..	0	0	0	0	0	0	0	0	0	2.2	1.5	0
Ste. Madeleine ..	0	0	0	0	0	0	0	0	0	1.4	0.4	1.0
1932.												
Orange Grove ..	0	0	0	0	0	0.8	1.6	8.4	0.3	0	2.2	1.4
Caroni ..	0	0	0	0	1.4	2.2	4.8	16.0	6.2	7.2	7.3	3.5
Woodford Lodge ..	0.8	0	0	0	1.2	23.1	2.1	0.6	7.8	1.5	6.2	1.3
Waterloo ..	0.2	0	0	0	2.2	3.3	0.8	0.2	0.6	6.6	2.7	1.5
Brechin Castle ..	0	0	0	0	0	0	0.5	1.3	0.4	1.8	1.3	1.0
Esperanza ..	0	0	0	0	0.4	2.1	2.1	1.3	4.5	0	1.2	0
Ste. Madeleine ..	0	..	0	0	0.5	2.5	4.2	1.5	4.9	0.7	3.3	7.7

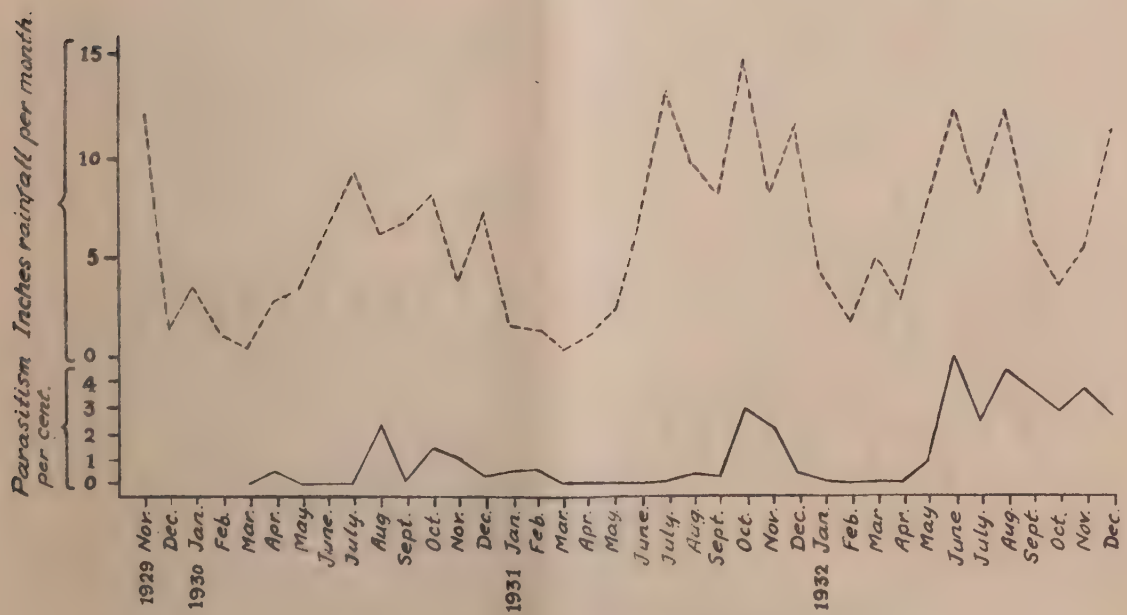
Parasitism Inches rainfall per month. per cent.
15
10
5
0
4
3
2
1
0
1929 Nov. Dec.
1930 Jan. Feb. Mar. Apr. May June July Aug Sept. Oct. Nov. Dec.
1931 Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec.
1932 Jan. Feb. Mar Apr. May June July Aug. Sept. Oct. Nov. Dec.

FIG. 1.—*The relation between Dry Season Rainfall and occurrence of Anagrus urichi.*

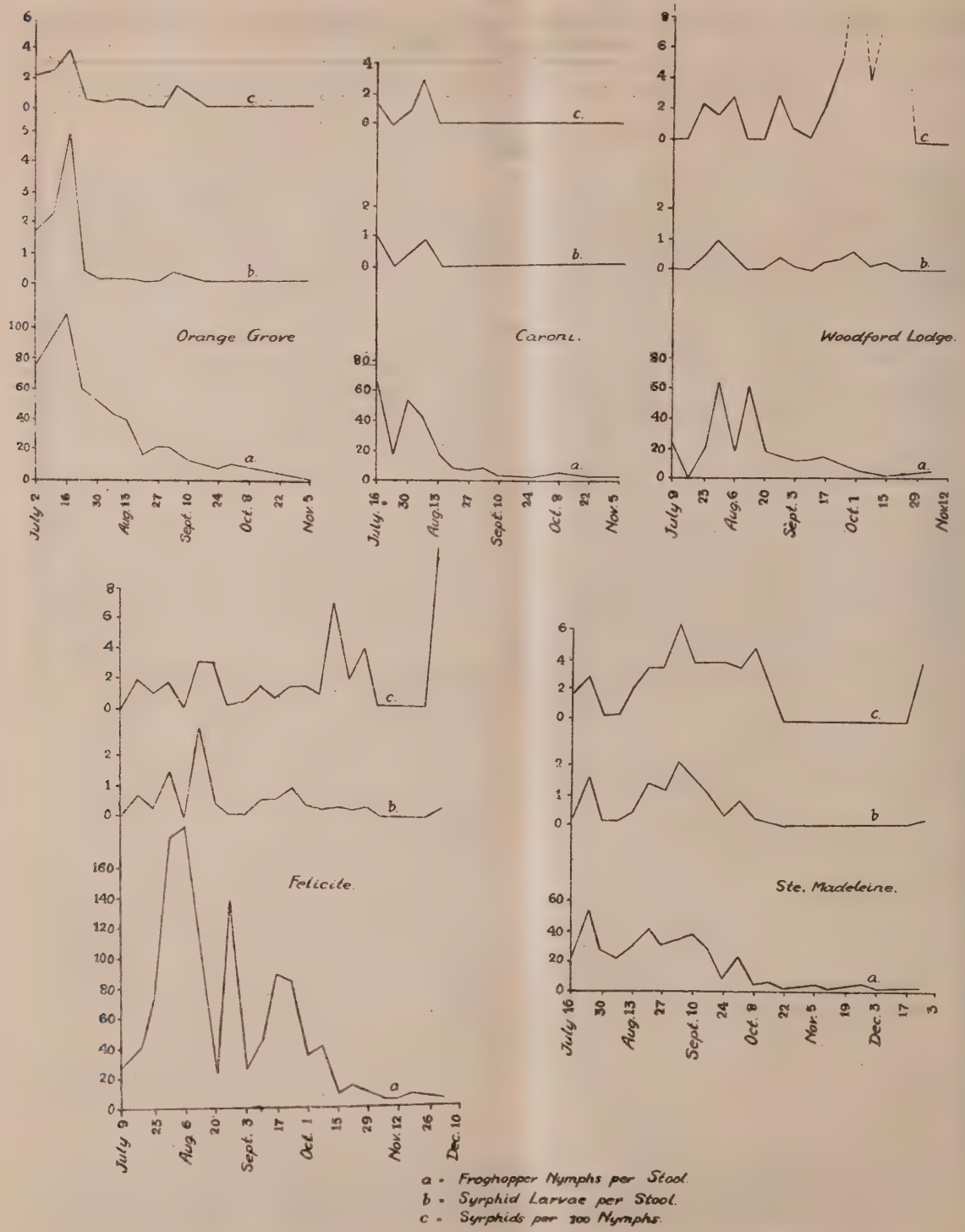
Orange Grove
Caroni.
Woodford Lodge.
Felicite.
Ste. Madeleine.
a.
b.
c.
July 2 16 30 Aug. 13 27 Sept. 10 24 Oct. 8 22 Nov. 5
July 16 30 Aug. 13 27 Sept. 10 24 Oct. 8 22 Nov. 5
July 9 25 Aug. 6 20 Sept. 3 17 Oct. 1 15 29 Nov. 12
July 9 25 Aug. 6 20 Sept. 3 17 Oct. 1 15 29 Nov. 12 26 Dec. 10
July 16 30 Aug. 13 27 Sept. 10 24 Oct. 8 22 Nov. 5 19 Dec. 3 17 31
a - Froghopper Nymphs per Stool.
b - Syrphid Larvae per Stool.
c - Syrphids per 100 Nymphs.

FIG. 2.—*Curves illustrative of froghopper and syrphid incidence on five observation stations, wet season, 1932.*

experienced during the year 1931, must therefore indicate that very dry weather is appreciably more unfavourable to the parasites than to the froghoppers.

The first specimens of *A. urichi* were bred from froghopper eggs found in the soil of cane fields. Mr. F. W. Urich, Assistant Professor of Entomology in the Imperial College of Tropical Agriculture, however, suggested to the writer that the parasites must have difficulty in finding the host eggs in soil and that probably eggs in cane trash were chiefly attacked, these eggs later falling to the ground. Owing to the minute size of the insect (0.51 millimetres), it is impossible to observe its habits in the field. By the routine collection of the eggs from soil and from cane trash, however, and by separate incubation of these, it was possible to obtain the proportions of parasitised eggs from these two situations. The egg samples were collected in pairs, one member of the pair consisting of all the eggs from the trash of a selected cane stool and the other of the eggs from a strip of soil surrounding the same stool. The observations extend over the period October, 1931 to December, 1932, and the results are shown in Table II.

The full data were somewhat reduced in order to clarify the issue; pairs in which no parasitism was observed are excluded, and pairs in which one sample contained fewer than 20 eggs are also neglected, as their inclusion would have given undue weight to the parasite rate in eggs from cane trash.

Table II shows clearly that a significantly greater proportion of the eggs in trash was parasitised than of the eggs in soil, and with few exceptions, this applies also even to individual sample pairs. It thus appears that the host eggs laid in the soil, which are usually most numerous, are relatively innaccessible to this parasite, which accordingly is able to attack only a small proportion of the eggs of the pest insect.

Repeated attempts to breed *Anagrus urichi* in captivity have so far been unsuccessful; the length of its life history is therefore still unknown. The parasite has been seen to emerge from cultures of eggs ten or twelve weeks after they had been taken from the field, so that its life cycle is probably longer than that of its host. Accordingly, there is no indication that this species can ever become an efficient "planter's ally" either by natural or artificially assisted propagation. The studies further indicate that no introduced *egg* parasite is likely to make any appreciable difference to froghopper multiplication unless it differs widely from this species in length of life cycle and general physiological relations. These desiderata are not likely to occur within the genus *Anagrus*.

(*b*) *Predators*.

The predator which has received detailed attention during the year 1932 has been the larva of the syrphid fly *Salpingogaster nigra* Schiner. This species was regarded by Kershaw as probably the most important natural enemy of the froghopper (3, 4), but experience has shown that, at any rate without artificial assistance, this species has failed to gain ascendency over its host in the cane fields.

In previous years, the method adopted in population studies on this insect involved counting the number of syrphid larvae, each month of

Table II.

Illustrating the distribution of *Anagrus urichi* between trash and soil.

Percentage No. of Parasitised Eggs in	
Trash.	Soil.
2.84	2.00
5.26	0
10.81	0
2.00	0
2.02	1.00
1.12	1.00
4.79	0
1.54	1.50
0	0.50
0	1.25
2.04	0
1.05	0
14.14	0
3.51	0
13.33	0
4.17	0
5.40	0
2.08	0.19
1.04	0
0.98	0
4.04	0
0	1.64
39.21	8.14
37.50	2.65
0	1.67
15.08	1.74
22.60	8.30
4.84	0
14.11	0
0.80	0
24.08	0
2.34	0
0	13.04
6.58	0
1.85	0
13.72	0
3.86	0
8.00	22.92
Total 276.73	67.54
Mean 7.28	1.78

By the method of Fisher (1, p. 107), it can be shown that "t" = 3.1982 and "n" = 74.

"P" is accordingly less than 0.01, and the observed difference is therefore definitely significant.

the year, which were encountered in miscellaneous collections of a hundred froghopper spittle masses. This method is satisfactory for infestations in grass, but is not accurate for cane field work, where the froghopper populations are discontinuous and where the froghopper population associated with a single stool, rather than with an arbitrary number of hosts should be considered. Accordingly, during 1932, the practice has been to examine ten stools per week in each of a number of special areas and to determine as accurately as possible the number of froghopper nymphs and of syrphid larvae associated with every stool. In this way, it has been possible to record the variations in absolute syrphid populations as well as to determine more accurately the relation of the syrphid population to that of the froghopper.

Studies were made at the following estates: Orange Grove, Caroni, Woodford Lodge, Felicite and Ste. Madeleine. In Fig. 2, the weekly values representative of the number of froghopper nymphs per stool, the number of syrphid larvae per stool and the number of syrphid larvae per hundred froghopper nymphs, are plotted against the date, for each of the observation stations. The figures illustrate the rise and fall of the successive froghopper broods and show that, like its host, the syrphid also arises in more or less definite broods, which seem to be related to those of the froghopper, as the maximum development of the syrphid brood occurs at or about the maximum development of the nymphal froghopper brood. The syrphids thus develop at the theoretically best time to control the host.

Soon after syrphids have reached their maximum, the numbers of froghopper nymphs decline, but this does not necessarily indicate that the predator is exerting a significant controlling effect, as even in the absence of controlling factors, there is an inter-brood period when froghoppers are comparatively few in number. In order, therefore, to examine the influence of a syrphid population on froghopper numbers, a different approach is necessary.

Guppy (2) states that one syrphid larva may destroy 40 froghopper nymphs in the course of its development. Accordingly, if a syrphid population equal to 2.5 per cent. of the froghopper population could be maintained during the whole period in which nymphs are present, this should theoretically keep the froghopper in complete control. Nevertheless, greater relative populations than this have been recorded on many occasions (9), following which, so far from control of the froghoppers resulting, the same fields have developed quite severe blight, and this experience has indicated the necessity of making a thorough study of the conditions of control by predators.

The individual stool records show that, while the syrphid population in an area occupied by ten stools might be quite high, a certain number of stools invariably supported froghopper nymphs but no syrphids, while other stools, and these not necessarily the most heavily infested with froghoppers, might support several syrphid larvae. The problem thus becomes somewhat analogous to that of random oviposition among internal parasitoids. In general, therefore, the mortality actually caused by the predator is less than that which would occur if the larvae were evenly distributed amongst the infested stools.

The study of predators in the field presents many difficulties which are not encountered in the study of internal parasites. Thus, if an insect population be found to be attacked by internal parasites, say to 50 per cent. then it follows that only 50 per cent. of the host population at that time will survive. In the case of a predator, which may destroy many hosts in the course of its life, there is little to indicate what proportion of the host population, associated with it at any time when counts are made, will escape its attentions, for it is not possible to determine how many hosts have already been consumed. The case of *S. nigra* is relatively simple, for it is known that about 40 hosts are necessary to enable development to occur, and this syrphid moreover, is specific, or nearly so, in feeding habits. If sufficient observations are made, therefore, we may assume that all the syrphids at the time of observation have already consumed half their normal quota of hosts, that is, 20, and will still devour 20 more hosts if these are available. While the results so obtained will involve a rather large error, they are probably sufficiently accurate for purposes of illustration.

A second difficulty arises from the increasing unavailability of hosts as more and more nymphs emerge into the adult condition. While the froghopper nymphs are increasing in numbers, that is, prior to the height of the nymphal outbreak, this effect is more than counterbalanced by the hatching of eggs to give rise to nymphs. After the maximum of the brood, however, there is an increasing number of individuals about to emerge as adults, which would be included in the counts as liable to attack by syrphids, when in reality their chances of attack are remote.

Another difficulty proceeds from the irregularity of predator distribution. The syrphid larva is relatively immobile and is also a somewhat delicate insect. Under ordinary cane field conditions, it seems to be unable to move from one stool to another, and is unable to survive for even short periods, out of the very specialised climate of the interior of a spittle mass. Migration from stool to stool probably only occurs when (1) the fields are very grassy, with a froghopper population on the weeds and (2) when a light "*boucan*" of trash extends between one stool and the next and the soil is very moist. Migration of this nature is thus of very exceptional occurrence and it is practically certain that it was never significant in the cases treated here.

Table III.

Typical record of froghopper and syrphid incidence from one observation station.

SYRPHID INCIDENCE.—STE. MADELEINE, 1932.
FIELD H.H.15. *Date : 27th August.*

Stool No.	No. of Nymphs.	No. of Syrphids.	Notes.
1	48	0	Green
2	85	8	Muscardine
3	22	0	4 per stool.
4	16	0	Adults 16
5	26	1	p.s.
6	25	0	
7	29	0	
8	10	0	
9	21	1	
10	18	1	

Mean Nymphs per Stool	..	30.0
Mean Syrphids per Stool	..	1.1
Syrphids per 100 Nymphs	..	3.6

Reference to Table III, which shows a record of one week's observation at a particular estate, will indicate the irregularity of the distribution.

On this date, there were 11 syrphid larvae present in the ten stool area. If the distribution had been even and each had, after this date, devoured a further 20 froghoppers, the nymphal froghopper population would have been reduced by 220, giving a control of 73.3 per cent. It is evident, however, that the eight syrphids in stool No. 2 could at most only destroy 85 froghoppers and the syrphid in stool No. 10 could only destroy 18, assuming that the residual quota of each was 20. The population would therefore be reduced by 143, instead of 220, and, the control effected would be $\frac{143 \times 100}{300}$, that is, only 47.6 per cent. instead of the 73.3 per cent. expected from the relative sizes of the populations.

Such irregularity of distribution is the general rule, for at no observation station during the year was every one of ten stools found to support syrphid larvae, even when the number of larvae was greater than the number of stools. It thus follows that syrphids tend to exert less than the maximum possible controlling effect when the froghopper populations are small or when the syrphid populations are large.

In a natural habitat, however, such as a shaded patch of grass in a forest clearing, where froghopper populations are more diffuse and where even the feeble ambulatory powers of the syrphid larvae enable them to distribute their activity over the whole area, the control effected would appear to depend mainly on the relation of the number of syrphids to the number of froghopper nymphs. A syrphid population capable of controlling the host in natural conditions would probably be significantly less effective, therefore, if maintained at the same intensity in a cane cultivation.

The fact remains, that with the more detailed work on this predator which was carried out in 1932, there is still no reliable evidence of the degree of control which it can occasion. To obtain such evidence seems to require observations over a larger area, taking into account the relation between the magnitude of the nymphal and adult froghopper population, if possible in a district where green muscardine fungus is at a minimum. Nevertheless, the data afford a basis for making a rough estimate of the control brought about at each of the observation stations in 1932, if certain rather gratuitous assumptions be made. Assuming that every syrphid at the time of observation had consumed half its total complement of hosts and had therefore the necessity to consume twenty more after the time of observation in order to complete its own development, that the nymphal populations remained otherwise constant (*i.e.*, that no further significant hatching of eggs or emergence of adults occurred until this was accomplished) and that there was no reduction of the syrphid population due to natural enemies, it is possible to estimate the size of the froghopper populations which would have survived, had syrphids not been present. By comparing the figure so obtained with the populations which were actually recorded during the period, a measure of the control is found, as in Table IV.

Table IV.

Estimated control of froghoppers brought about at five stations during the wet season of 1932.

Station.	Period of Observations.	Estimated Control.
Orange Grove	June 29-Nov. 18	26.1 per cent.
Caroni	July 16-Nov. 18	18.7 do.
Woodford Lodge	July 4-Dec. 31	19.3 do.
Felicite	July 4-Dec. 31	17.0 do.
Ste. Madeleine	July 4-Dec. 31	40.0 do.

There is an indication, therefore, that while the larvae of *Salpingogaster* do not give a very high degree of froghopper control, even when they are prevalent in the cane fields at an early stage in froghopper development, the effect on froghopper population is probably significant.

It is certain that syrphid populations are preyed upon to some extent by other organisms. A certain number of puparia have been observed with the exit holes of parasites in them, though up to the present, the parasite concerned has not been discovered and the degree of destruction due to this cause is unknown. The populations also must be reduced by the simultaneous presence of several larvae in one cane stool which has very few froghopper nymphs associated with it. In such cases, probably only one larva will survive, the remainder dying from starvation or from cannibalism.

This insect does not appear to be a very favourable subject for artificial fostering in order to control froghopper. It is apparent that populations must be maintained in the cane fields at a considerably higher level than they are normally at present if any relief is to be felt, and indeed, the populations must exceed the theoretical requirement, owing to the habit of random oviposition. Owing to the almost complete absence of froghoppers from the cane fields during a normal dry season, it would be necessary to breed also an adequate supply of hosts in captivity in order to maintain a stock of the insects for liberation on the commencement of the rains (2, 3), a problem which in itself presents many difficulties.

(*c*) *Entomogenous Fungi.*

The Green Muscardine fungus (*Metarrhizium anisopliae*) has long been recognised as a most important natural enemy of the froghopper (*vide* Williams, *loc. cit.*, pp. 82-85). Unfortunately, the numerous trials of artificial propagation of this fungus which have been made, show all too clearly that its development depends so intimately upon climatic conditions, that artificial spreading of fungus spores is followed by results which in the main are not proportionate to the expense and labour involved. When conditions are unfavourable for the natural propagation of the fungus, artificial dissemination is of no avail, and usually, though not invariably, there is no lack of the fungus when conditions become favourable. It should be noted that occasionally, one cane field will be found to contain a large number of froghoppers affected by the fungus, while an adjoining field may show no signs of it. In such cases it seems probable that deliberate scattering of the spores would be attended with useful results, though since the fungus has to be prepared carefully in advance, such cases would appear to be too few in number to justify the maintenance of a permanent plant for the purpose of raising spores.

While the presence of the fungus in the cane fields is a matter of common experience it is remarkable that no froghoppers attacked by it have been ever found by the writer in forest habitats. Such localities, indeed, would be expected to be especially favourable to green muscardine, on account of the greater conservation of atmospheric humidity which obtains. Mr. Urich reports having found a Scarabaeid larva attacked by the fungus, however, in such a habitat, and it seems possible that the green muscardine is normally present in forests, but that insects attacked by it rapidly become the prey of numerous small predators and scavengers, among which ants may be prominent. Support is given to this hypothesis by Williams' observation (*loc. cit.* p. 83): "... the specimens dead and dying from the fungus fall an easy prey to predaceous ants and are often carried away by them before they have time to disseminate their spores." This has been confirmed by more recent personal observation.

This fact makes it a matter of some difficulty to assess the degree of control effected by green muscardine: counts in the cane fields of the number of dead and moribund froghoppers affected by the fungus will not only vary directly as the abundance of green muscardine, but also inversely as the number of scavengers.

It is possible, however, to derive some idea of the efficiency of this means of control from a critical examination of the nymphal and adult populations of an area in which the fungus is known to be operating. The following extract from the records (Table V), illustrates one case of very complete control effected during the year 1932.

Table V.

Date.	Nymphs per Stool.	Adults per Stool.	Blight.	Notes.
1st May	18	0	0	—
9th May	55	0	0	—
16th May	65	0	0	—
23rd May	159	0	0	A few adults with green muscardine.
8th June	100	0	0	—
18th June	50	5	0	Nymphs with green muscardine.
25th June	5-10	2	0	—
2nd July	5	1	0	—
9th July	5	3	slight.	Field flooded 7th July.

In this particular field, therefore, there was a very large first brood outbreak of nymphs, amounting at the height of the brood to about 160 per stool. Green muscardine was prevalent very early in the year, and in spite of this high population of nymphs, adults did not exceed 5 per stool, with the result that no appreciable blighting resulted. It is noteworthy that even nymphs were found to be freely affected by fungus and that syrphid larvae were not found in this field, although a special search was made for them.

This observation suggested the possibility of extending the population studies over a much wider area, and thanks to the generosity of the management of the Caroni Sugar Estates, Ltd., a special survey was put into operation. A number of selected fields were visited once during the week and careful counts were made in them of the number of froghopper nymphs and adults associated with each of three stools, these numbers being carefully recorded. The mean of the three counts was taken to represent the condition of the field at the time, and the presence of green muscardine was noted, when this could be detected. As a matter of fact, symptoms of fungus attack were found in practically all of the fields, certainly in all where the initial froghopper populations were heavy.

At the conclusion of the season, the records were scrutinised and certain fields in which the froghopper incidence had been of very short duration were excluded from further attention. The weekly populations from all the others, some 200 in number, were added together, nymphs and adults being considered separately and the results are shown graphically in Fig. 3.

The curves show that two well marked nymphal outbreaks occurred, the records commencing subsequent to the peak of first brood emergence, and the curves consequently show only the decline of this brood. In the case of the second brood, the maximum nymphal development is followed about a week later by a peak in the curve of adult emergence, which, however, is at a much lower level. There is later a small increase in the nymphal populations, indicating the appearance of a small third brood of nymphs, and here again, the adult maximum is much smaller, after which, there is a continuous decline in the populations, which did not again become sufficiently large to cause appreciable damage. It is thus evident that some powerful controlling factor is operative during the whole period under review, which has reduced very appreciably the number of advanced froghopper nymphs or of young adults or both, resulting in adult populations which are not commensurate with the nymphal populations, a control whose effects are particularly well marked at the time of the emergence of the second brood.

The degree of control effected by this factor is difficult to assess. The duration of nymphal life is in the neighbourhood of five weeks, but this does not mean that the adults present in a field on any given date were all derived from the nymphal populations of five weeks previously. During the emergence of nymphs, individuals of all ages can be found at any time; some of these will become adults in five weeks' time, others, being more advanced, will emerge as adults in a much shorter time. Moreover, adult froghoppers are stated to live for as long as a month, so that it is not possible to relate a given nymphal population to the resulting number of adults. It is patent, nevertheless, that only a small proportion of the nymphs observed in this area gave rise to effective adults. Some of the observed mortality might be due to the activity of syrphid larvae, but detailed observations showed that syrphids never attained significant proportions in most of the fields, that a large number of fields did not contain syrphids at all and finally, that syrphids were not regularly present after the end of August in any field.

It has been suggested that a major part of the observed control was due to the widespread floods which occurred on this estate during weeks ending 9th July and 13th August. Reference to Fig. 3, will show that, while a certain population decrease may be due to this cause, the greater part of the froghopper mortality was independent of it, since the first flood (7th July) occurred immediately before the emergence of a very large second brood of nymphs, which gave rise to a relatively small number of adults before the second flood occurred. It is possible that the prevalence of green muscardine was assisted by the humid conditions brought about by the floods, but most of the control seems to be distinctly independent of the direct effect of flooding.

Green muscardine, as has already been indicated, was known from counts of infected insects to be unusually prevalent in this area from the beginning of the wet season; large potential froghopper populations were present in the fields in the early part of the year, but failed to develop into correspondingly large adult population; it has been shown that the direct effect of submergence of the fields and the activity of syrphid predators could not be responsible for the observed facts. It is therefore concluded that green muscardine fungus was predominantly responsible for the control which occurred. It may be added that numerous dissections of froghoppers during the whole period studied failed to indicate the presence of any internal parasite.

A similar survey was attempted on the adjoining estate of Orange Grove. The study in this area was commenced at a later date, however, and the observations were necessarily limited to records over a much smaller area. The results are shown graphically in Fig. 4, and cover the period of activity of the second and third broods of the year 1932. Here again, there was a considerable disparity between the magnitude on the second brood nymphal and adult populations, but the third brood, which reached damaging proportions, showed no such dissimilarity, and the adults of this brood were as numerous as were the nymphs.

At this time, there was a period of dry weather (*petit carême*), which presumably limited the activity of green muscardine at Orange Grove and consequently removed the disparity between the nymphal and adult populations. On the other hand, there was a similar dry interval at Caroni Estate, which was not accompanied by an approximation of the numbers of adults to the numbers of nymphs. The reasons for this dissimilarity between the two cases are somewhat obscure, but may be explicable according to one or other of the following tentative suggestions: (1) It is possible that at Caroni Estate, reduction of the earlier broods had been so efficient that their surviving progeny were insufficient to give rise to a large third brood. This is unlikely however, as the graph (Fig. 3) seems to show a maintenance of the difference in numbers of nymphs and adults. (2) The third brood outbreak occurred at Caroni on a heavy soil type, while at Orange Grove, the soil is of a much lighter texture. It seems possible that, in the absence of a high rainfall, a humid atmosphere is maintained for a longer time over the heavy soils than over the lighter types which dry out much quicker

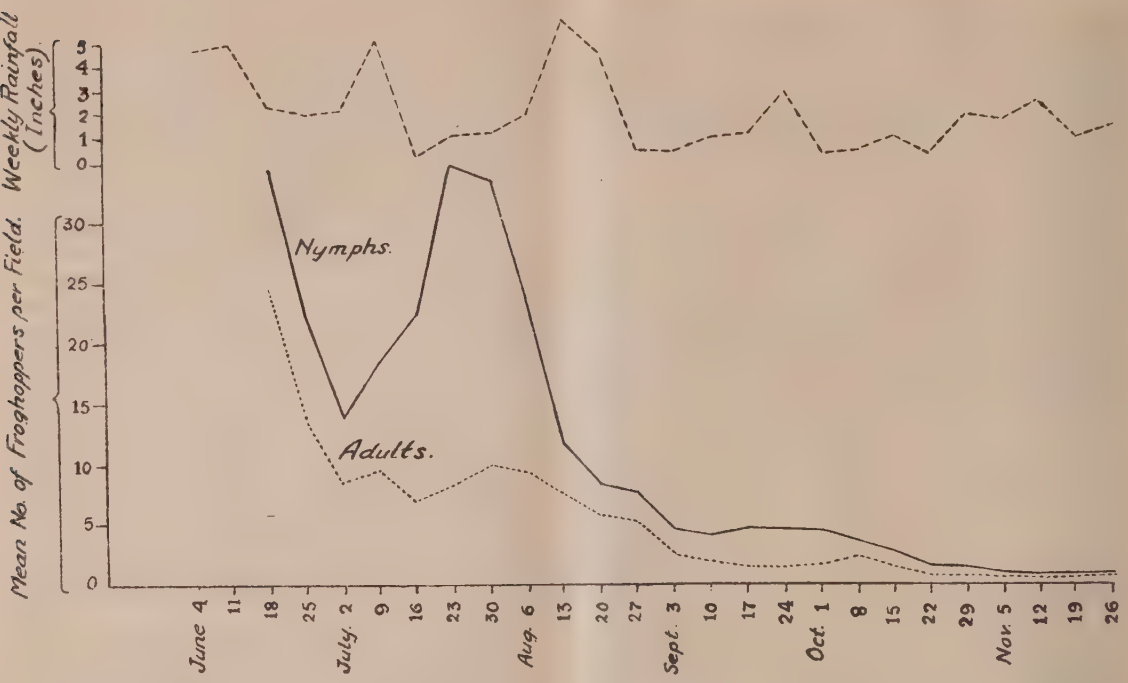
Mean No. of Froghoppers per Field. Weekly Rainfall (Inches).
Nymphs.
Adults.
June 4 11 18 25 July 2 9 16 23 30 Aug. 6 13 20 27 Sept. 3 10 17 24 Oct. 1 8 15 22 29 Nov. 5 12 19 26

FIG. 3.— *Variations in the intensity of froghopper nymphal and adult infestations at Caroni Estate, Wet Season, 1932.*

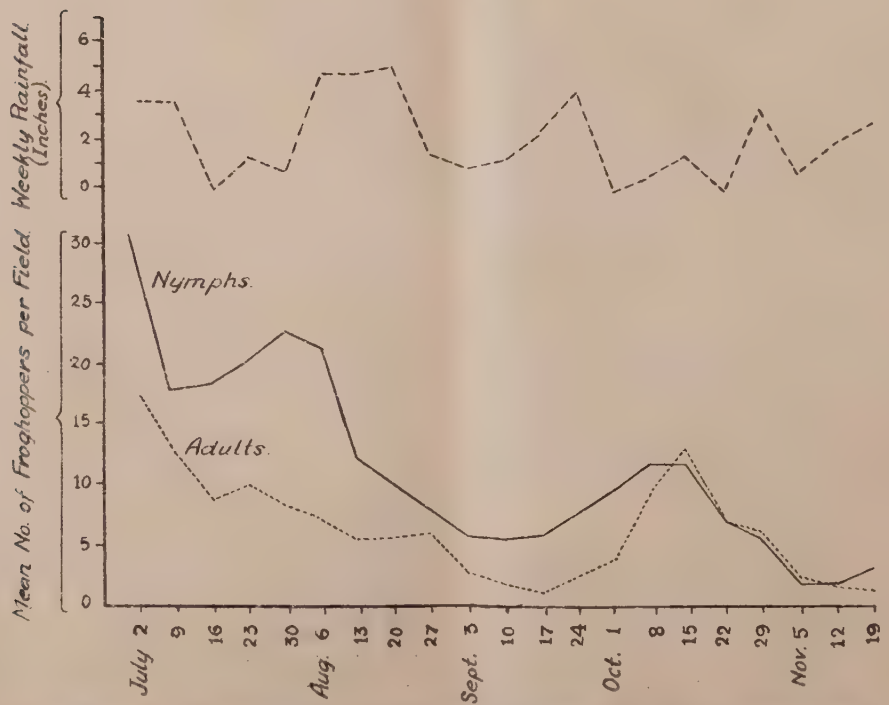
Mean No. of Froghoppers per Field. Weekly Rainfall (Inches).
Nymphs.
Adults.
July 2 9 16 23 30 Aug. 6 13 20 27 Sept. 3 10 17 24 Oct. 1 8 15 22 29 Nov. 5 12 19

FIG. 4.— *Variations in the intensity of froghopper nymphal and adult infestations at Orange Grove Estate, Wet Season, 1932.*

in periods of drought. This suggestion should be capable of experimental verification. In this connection, it is of interest to note that the two principal areas where large third brood development occurred, viz. Orange Grove and Felicite Estates, are both characterised by a relatively light soil.*

It is evident from the recorded observations that at Orange Grove and Caroni Estates during 1932, restricted froghopper outbreaks were marked by a disparity between the nymphal and adult populations, while the incidence of a severe attack was characterised by the development of adult populations of the same order of magnitude as the nymphal populations had been.

The early appearance of green muscardine in 1932 over a wide area seems once more to be the effect of a wet dry season. Following on the very severe dry season of 1931, green muscardine was not prevalent in the cane fields until the middle of September, by which time, a relatively unchecked second brood had brought about an immense amount of damage to canes.

Reference to the rainfall data given in Fig. 1 will show that, although there was a very severe dry season at the commencement of 1931, the wet season rainfall was in excess of that in 1932. This fact indicates that absence of green muscardine at a particular time in the wet season does not necessarily mean that conditions of climate at the time are unfavourable for the growth of the fungus, but rather that there is little or no fungus present, in consequence of the dry weather of the early part of the year. It is known that this fungus attacks a variety of hosts in the cane fields and that a certain degree of humidity is essential for its growth. If the dry season, therefore be very wet, the fungus is able to continue its reproduction, even in the absence of its froghopper host on other insects, particularly those which frequent the most humid habitats. With the advent of normal wet season rainfall, there is an abundance of the fungus already in the fields which is able to attack the froghopper without delay. If the dry season is very severe, on the other hand, reproduction of the fungus on practically all its hosts presumably becomes impossible, with the result that the prevalence of suitable weather conditions in the wet season must continue for a considerable interval before the fungus becomes dominant.

If this argument be correct, it follows that the earlier attempts to spread the fungus artificially at the beginning of the year were probably sound. Their failure to control the froghopper appears to be due to the uncertainty of weather conditions at the commencement of the wet season, when the attempts were made and to the difficulty of having a very large stock of viable spores available when the most favourable weather conditions occur. Briton-Jones has shown that in certain circumstances, artificial spreading of spores of the fungus is definitely attended with an increased mortality of froghoppers, but he considers the method too uncertain to be of great practical value.

Williams has already suggested that the reaction of green muscardine to climatic conditions "is probably one of the ways in which rainfall brings about its important effect on the prevalence of blight in the different seasons". While the present studies have only proceeded for a limited time, it is manifest that the results endorse this suggestion completely.

The relation between the severity of the dry-season and the froghopper populations, resulting in decreased froghopper damage after a wet dry-season, can hardly be the direct effect of the dry-season climate on the insect. In very dry weather, one would expect a mortality of eggs to occur to a greater extent than in moist weather, and this in fact seems to be the case since, as has been mentioned, the severe dry-season of 1931 was followed by the appearance of a small first brood, considerably below its average dimensions. Indeed, on certain estates, the first brood was unnoticed except for very occasional froghoppers here and there, and there was scarcely any resulting blight, all the damage in that year being due to the later broods. A wet dry-season, on the contrary, would be expected to permit of froghopper breeding through the months when the insect is normally in abeyance, with a consequent increase in the size of the first wet-season brood, if there be no biotic controls operating. It is true that large proportions of dead eggs were found in the cane fields during the opening months of 1932, when the weather was unusually wet for the time of the year, but as there are no records of dry-season egg mortality for other years, it is possible that this phenomenon is of regular occurrence, probably to even greater extents in dryer seasons. Moreover, hatching of the viable eggs during the official dry-season would increase the proportion of dead eggs in

* Since writing the above, Professor Ballou has kindly drawn my attention to some published details which lend countenance to this hypothesis. Thus, Nowell points out that although considerations of rainfall and topography would seem to indicate very suitable conditions for cacao culture in St. Vincent, it is a comparatively dry-climate crop, namely cotton, which has proved successful in the past. Grenada, with its essentially similar climate and topography has cultivated cacao successfully and is apparently not a suitable cotton locality. The soils of the two islands, however, show outstanding differences, that of St. Vincent being very light and offering little resistance to the passage of water, while the Grenada soils are moderately heavy and are retentive of moisture. Nowell considers that as a consequence of the soil condition in St. Vincent, the atmospheric humidity is much lower than would be expected from the rainfall statistics and that in spite of its heavy rainfall, St. Vincent is a relatively dry island. (*Vide*: Report of the Agricultural Department, St. Vincent, 1915-16, p. 25; Nowell, W., Diseases of Crop Plants in the Lesser Antilles; London, n.d., pp. 194-5.)

the field, without reducing the size of the next froghopper brood. A large first brood may therefore be expected after a wet dry-season and this did actually occur in 1932. The published records of previous years of similar weather conditions, unfortunately, do not give information as to the size of the first brood with which this experience can be compared.

There can be little doubt, in view of these observations, that the prevalence of green muscardine is a most significant factor in restricting froghopper damage and that its prevalence is dependent upon the maintenance of humid conditions. Humidity during the dry-season is particularly important, and if it is maintained at a sufficiently high level, the fungus may be effective from the commencement of the froghopper outbreak. On the contrary, if the dry season is of normal or excessive severity, the appearance of the fungus may be delayed so long that widespread damage occurs before its incidence. If this theory of the relation between dry-season climate and froghopper activity be correct, it should be possible to correlate differences in the severity of say, a second brood outbreak from place to place, with differences in the degree of severity of the dry-season. Now in 1932, a part of Waterloo Estate was exceptional in experiencing very severe second brood blight. The fields affected were principally those which had contained large populations of froghoppers in 1931, or adjoining fields. Scrutiny of the rainfall records shows that in this area, the dry season rainfall was considerably below that of the estates where limited second brood blight occurred, as reference to the following table will show.

Estate.	Rainfall, Dry Season, 1932.	Second Brood.
Orange Grove ..	29.38 inches.	Small.
Caroni ..	27.87 do.	Small.
Ste. Madeleine ..	19.11 do.	Small.
Waterloo ..	16.24 do.	Very severe.

Dry season rainfall was thus smallest on the estate where the greatest second brood development occurred, and was actually 11.5 inches below that of the estate where natural froghopper control was particularly evident. While the dry-season rainfall at Ste. Madeleine was higher, this area also seems to have experienced a distinctly drier dry-season than Caroni Estate, without a correspondingly large froghopper outbreak. This appears to be due to the smaller initial populations of froghoppers at Ste. Madeleine, in consequence of the relatively light outbreaks in this area during the year 1931.

Since, then, the general level of froghopper activity depends on the prevalence of natural enemies, of which green muscardine fungus appears to be the chief, with the syrphid fly as a much smaller, though still significant ally, and since the prevalence of these enemies is connected with dry-season conditions in particular, the observed four or five years interval between periods of especially intense froghopper activity should be ultimately due to a weather cycle. Dr. C. B. Williams mentions (in correspondence) that according to meteorological investigation, the Trinidad rainfall varies by an accentuation of the severity of the dry-season and of the *petit carême* in years of maximum and minimum sunspots, which suggests a possible basis for periodicity in the attacks. With a view to forecasting the probable severity of damage in considerable advance, this line of study seems to be worthy of attention.

The studies show that weather conditions, more particularly the degree of severity of the dry-season, have a controlling effect upon the natural enemies of the froghopper in the cane fields, and this effect is in the same direction for all the enemies studied, *i.e.*, for an egg parasite, an insect predator and an entomogenous fungus. Further, two of these enemies are of significant value in controlling froghopper under certain conditions and there is good evidence to show that the fungus, when conditions are favourable, is able to reduce a potentially large froghopper population below the level at which severe and widespread injury occurs. Very severe dry-seasons have a literally decimating effect upon the enemies, with the result that such seasons, which appear to be of periodic occurrence, are followed by excessive froghopper activity. This fact has been long suspected, but in view of the evidence, of a numerical nature, which is now to hand, the primary importance of the threefold climate-parasite-froghopper relationship may be regarded as well confirmed.

Finally, the extreme importance of the dry-season conditions in the economy of natural enemies adds precision and importance to the suggestion already made (7) that any natural enemy introduced to control the pest must be definitely adapted, either in life history or physiology to survive conditions of extreme drought.

The author is indebted for advice, criticism and encouragement in the preparation of this paper, to many members of the Staff of the Imperial College of Tropical Agriculture, particularly to Professor Ballou and Mr. F. W. Urich and for many helpful suggestions in the presentation of the data, to Dr. S. C. Harland.

Summary.

1. An account is given of studies on the incidence of egg parasites of the sugar-cane froghopper in Trinidad. The highest average figure for

the whole area during the period studied, appears to be in the neighbourhood of five per cent. The chief egg parasite is *Anagrus urichi* Pickles, other species apparently being of only occasional occurrence. The incidence of this parasite is affected by dry-season conditions; after a wet dry-season, the parasite becomes generally distributed and relatively abundant early in the year, but a severe dry-season delays its appearance in appreciable numbers very markedly.

The parasite is definitely more abundant in host eggs laid in cane trash than in eggs laid in soil, a fact which militates against its efficiency in controlling the host.

2. Evidence is given, indicating that the syrphid fly *Salpingogaster nigra* Schiner is a significant factor in controlling froghoppers under cane field conditions. This predator is adversely affected by severe dry-season conditions which delay its appearance in quantity in the fields. Its efficiency is also reduced by the feeble powers of locomotion of the larva and to an unknown degree by its liability to attack by internal parasites. Under favourable conditions, the degree of control brought about by this insect is estimated at about 20 to 40 per cent.

3. The most important natural control of the froghopper is the green muscardine fungus *Metarrhizium anisopliae* Sorokin, and detailed evidence is given showing that this fungus can reduce a potentially large froghopper population below the level at which serious damage occurs. The results of studies show that the fungus is governed by weather conditions, severe dry weather at the commencement of the year delaying its appearance as a significant control until much froghopper damage has occurred. The link between the severity of the dry season and of the subsequent froghopper outbreak thus becomes explicable.

4. The evidence thus indicates clearly that a severe dry season acts adversely on all the chief natural enemies of the froghopper, so that egg parasites and predators are most scarce at times when, in consequence of the absence of green muscardine, froghopper populations tend to multiply most rapidly.

5. It seems certain that the control which occurred after the humid dry season of 1932 was biological in nature, and was due in chief measure to the benign influence of the dry-season climate on green muscardine fungus.

6. It is shown that counts of froghoppers in the field which are affected by green muscardine fungus do not give a trustworthy measure of the activity of this control. The suggestion is made that this factor may also operate to a very significant extent in forest habitats.

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REVIEW.

THE B.D.H. BOOK OF REAGENTS.

The British Drug Houses Ltd., London, 1933. Second Edition. pp. 54, Price 2*s.* 6*d.*

This book gives particulars of a number of gravimetric and colorimetric determinations, which depend upon the use of special organic reagents. By their application in spot tests, small traces of various metallic compounds and other substances may readily be detected, and often accurately estimated. In this way, much waste of time is prevented, and expensive materials are saved. The technique applied is a development of inorganic micro-analysis. It involves the production of characteristic colour changes, or the formation of recognisable crystals in small test-tubes, spot plates, microscope slides or filter-paper strips. Altogether, some fifty specific tests are described, with full instructions for their performamce. Among them may be noted tests for aluminium, iron, phosphate, nitrate, calcium, magnesium, potassium, ammonium, zinc and copper, all of which are important components of biological materials and soils. The book supplies a real want in the agricultural chemical laboratory, as well as in the general analytical laboratory.

F. H.

CHEMICAL NOTES.

Compiled by the College Department of Chemistry and Soil Science.

The New Fauser Process of Fertilizer Manufacture.

Ammonium sulphate, ammonium phosphate, and other ammonia fertilizers were formerly made by running the appropriate acid into ammonia liquor. Since the reaction took place in a liquid and acid medium, the product was invariably damp and acid, and had to be dried further and neutralised before it could be used. The new Fauser process yields ammonium salts which do not require drying or neutralizing, but can be immediately applied in the field: the process can be used not only for making ammonium sulphate and ammonium phosphate but also compound fertilizers like ammonium sulpho-nitrate (Leuna Saltpetre) and ammonium sulpho-phosphate.

By this process, sulphuric acid in the form of a very fine mist, which is produced in a special atomizer, is sprayed into an atmosphere of dry ammonia gas. The reaction thus takes place in an alkaline and gaseous medium and produces directly a neutral and dry salt. The sulphuric acid mist, produced from acid of 52° Be, is introduced into the top of a chamber, while anhydrous ammonia gas enters through apertures disposed on the bottom. The resulting salt falls on to the floor of the chamber, passes through a number of openings, and is taken up and transported by a screw-conveyor. Small amounts of ammonia that adhere to the salt are removed by an air-blast, and are, of course, recovered. Since the salt so obtained has a micro-crystalline structure (which entails setting to hard and compact masses on storage, re-crushing, and difficulty in sowing uniformly), a regulated quantity of water is added to it while still on the conveyor, and owing to the peculiar construction of the conveyor the micro-crystals are converted into small round spheres, which after drying in a rotary dryer do not harden or cohere during storage. The heat-balance of this process is so favourable that all heat losses are covered by the heat neutralization. If the production exceeds 50 tons a day, the heat loss per apparatus is reduced and a more dilute sulphuric acid can, be used.—(*Chemistry and Industry*, Vol. LII, 1933, No. 4, p. 74.)

* * *

Distribution of Manure in the Field.

It has always been recognized that unevenness of distribution of artificial manures may cause local starvation or even poisoning in the crop, and much attention has been paid to the construction of manure drills and distributors of various kinds. In practice, the manure distribution is usually followed by some cultivating implement, the function of which is to mix the fertilizer with the soil.

Until recently, the degree of mixing attained by the various classes of implements was only a matter of conjecture, but an ingenious method has now been devised in Germany to render the particles of manure in the soil directly visible, thus enabling depth distribution studies to be undertaken in soil samples carefully removed from the field. The fertilizer is treated with anthracene before sowing, and after distribution and cultivation the samples are examined in ultra-violet light. By this means it has been found that the newer rotary cultivation gives a more uniform distribution than either the surface working implements or the plough. The extent to which these differences of location of the fertilizer affect the crop has not yet been extensively investigated, although on general grounds, thorough incorporation would seem to be desirable, particularly with relatively insoluble manures. (*Nature*, Vol. CXXXI, 1933, p. 445.)

* * *

Forest Fires in Relation to Soil Fertility.

In *Nature*, Vol. CXXXI, 3rd June, 1933, Professor Worley, of Auckland University College, New Zealand, discusses the disastrous effects of burning forests on clearing the land for agriculture. In many cases the resulting soil has a surprisingly low fertility, considering the luxuriant forest growth it supported, and therefore the fertility of a forest soil, as such, is little or no indication of its value for agricultural purposes. Much of this soil deterioration can be explained by the leaching out of soluble mineral constituents on removing the protecting vegetation, and on hillsides the rapid erosion is an obviously dominant factor. Professor Worley suggests an additional effect which is not often considered. Deep-rooted trees bring to the surface minerals such as potash, lime, and phosphorus, and render these available for other plants by depositing them on the forest floor in the humic layer. But some of the less common minerals are also rendered available in this way, such as copper and manganese, which occur in minute quantities in the soil and may play an important part in the growth of plants. For instance, Maquenne and Demoussy found that copper was concentrated in the actively growing parts of Karakara trees, although it is normally found only in minute amounts in the soil.

The remedy suggested is to grow deep rooted plants, which will have some chance of tapping the minerals which have been leached down, and will also tend to render available some of the mineral constituents of the sub-soil. The agriculturist often requires a quick-growing crop, and the comparatively slow-growing forest trees are less likely to suffer from mineral deficiency, but the part played by the less abundant mineral elements suggests an entirely new line of thought in the development of virgin soil.

SUGAR NOTES.

Compiled by the College Department of Sugar Technology.

Limit of Sugar-Cane Yield.

Dr. Prinsen Geerligs has recently stated that, during the last ten years, the production of sugar per acre has increased in Java by 30 per cent., and in Hawaii by 50 per cent. Similar increases have also been obtained in certain other sugar-producing countries, such as Formosa and the Philippines. It is possible to calculate the theoretical limit to increased production, assuming that the nitrogen content of sugar-cane is 0.084 per cent. of the weight of the whole plant (as it is in P.O.J. 2878 and H 109). Results of this calculation (which is based on the Mitscherlich law of growth), indicate that the maximum possible yield of such sugar-cane varieties is about 160 tons per acre, or about 25 tons of sugar per acre. These yields may be obtained only when the supplies of water and of plant nutrients are adequate, and when other environmental growth conditions are fully satisfactory. Several plantations in Hawaii have already recorded yields approximating to the theoretical limit, so that suitable modifications of the environment may yet lead to increased yields in other regions.

The theoretical 160 ton maximum is based on the assumption that the nitrogen content of the cane is 0.084 per cent. Since yielding ability is inversely proportional to nitrogen content, it would appear possible to exceed the 160 tons per acre limit by breeding new sugar-cane seedlings containing less than 0.084 per cent. nitrogen; the practical limit evidently has not yet therefore been attained.

* * *

Cultivation of Cane in Periods of Over-Production.

*W. E. Cross.**

In consequence of the restrictions upon sugar production imposed by law in Tucuman, some planters find themselves with areas of land which furnish a larger amount of cane than they are allowed to deliver to the factories. Under these circumstances the question has been raised of the advisability of cultivating the fields and it has been contended that the planter will have money by omitting cultivation, because even if the land is neglected the yield still will equal the plantation's quota of deliverable cane. The author points out that this is distinctly a mistaken policy. Neglected cane fields soon become weedy, the stand is greatly reduced, and there really would be no saving at all; the decreased yield would more than wipe out the saving from omission of cultivation.

A more logical plan is to confine the cane production to the best and richest lands of the plantation. The less productive portions should be ploughed and planted to some leguminous hay crop, preferably alfalfa. If the fields are very weedy it will be best to eradicate the weeds by a crop of *caupi* before planting alfalfa. If the restrictions on production are removed in a few years, the land that has been growing alfalfa will be found to be enormously productive when again planted in cane.—(*Inter. Sugar Journal*, Vol. XXXIV, No. 407, pp. 433-34.)

* Rev. Ind. Agr. Tucuman, 1932, Vol. XXII, Nos. 1-2, pp. 49-51.

* * *

Different Methods of Purifying Uba Cane Juice (including hot liming). *E. Haddon.*

In last year's official results giving the purity of the mixed juice for Natal factories are found the following figures: carbonatation, 84.29; cold sulphitation, 82.86; average of other factories with hot liming, 85.54; showing purity increases from mixed to clarified juice of 4.61, 1.60, 1.26°.

General practice in hot liming is to heat the juice to 140°F. (60°C.), add about 90 per cent. of the amount of lime which would be required to neutralize the sulphited juice, to sulphite to about 3 grms. of SO_2 per litre, to run into the correcting tanks, again lime to 8.7 pH, and finally to neutralize by phosphoric acid to 7.4 to 7.6 pH, the amount of phosphoric paste used being about 1 lb. per t.c.

It is found that in hot liming, the scums filter much better, due to the formation with the wax of a granular combination, which is insoluble, and easily separated by filtration. Better results are obtained by liming at 70°C., this hot liming method being of great assistance at the presses and the settling tanks.

But from the final published figures hot liming does not increase the recovery. Its advantages are: easier filtration of the scums; easier drying of the scums; and less sugar lost through leakages by bursting joints. On the other hand, a destruction of ten per cent. of the reducing sugars generally takes place.

Saillard has called attention to some results obtained in France in a beet factory, where, due to the very slimy nature of the carbonatation cakes, it was impossible to treat more than 500 tons of roots in 24 hours. After, however, adopting hot sulphitation at a temperature of 85°C. (0.2 grm. per litre) followed by liming and carbonatation, it was possible to slice at the rate of 1,800 tons per 24 hours, and without addition to the equipment.

The author considers hot liming quickly followed by sulphi-carbonatation (with or without the formation of an extra amount of lime salts to divide the scums) to be the best method in the case of Uba juice. He has applied it, finding that it gives a greater increase in purity and recovery than does ordinary hot liming.—(*Inter. Sugar Jnl.*, Vol. XXXV, No. 414, p. 244.)

TREND OF THE MARKETS.

[*The notes below are based principally upon running charts of the prices of the basic grades and upon general statistical information gleaned from contemporary publications and cablegrams and are intended to be a record of movements. An attempt is made, where possible, to indicate the market outlook at the time of going to press, but no responsibility for the accuracy and subsequent truth of such observations is assumed. Unless otherwise stated the prices quoted are spot, London.*]

COTTON.—The following are the official spot prices in pence per lb. of the Liverpool Cotton Association:

	American Mid.	*Egyptian F.G.F. Sakel.*
26th May ..	6.07	8.17
2nd June ..	6.37	8.54
9th June ..	6.12	8.26
16th June ..	6.18	8.30
23rd June ..	6.18	6.20
30th June ..	6.38	—
7th July ..	6.40	—
14th July ..	6.33	—
(15*th July*, 1932) ..	4.66	6.65

Prices have fluctuated more or less according to political reports and developments while the recent strength displayed in the raw cotton market has led to the general maintenance of values. A fair business has been done in West Indian Sea Island at firm prices which include 12*d.* to 15*d.*

* * *

SUGAR.—Prices on the Home Market have ranged as follows (c.i.f. per cwt.):

	Foreign.	*Preferential.*
	s. d.	*s. d.*
25th May ..	5 7½	10 4½
1st June ..	6 1½	10 10½
8th June ..	6 1½	10 10½
15th June ..	5 10½	10 7½
22nd June ..	5 8¼	10 4¼
29th June ..	5 9¾	10 6¾
6th July ..	5 11¼	10 8¼
13th July ..	5 7½	10 4½
(14*th July*, 1932) ..	6 1½	10 10½

The market after showing considerable activity at the beginning of June (a further 6*d.* having been added to the world value of Raw Sugar) has become easier under selling pressure. There has been a tendency to await developments either within the sphere of the article or in the broader field of international affairs. *C. Czarnikow, Ltd.*, state that "the steady depreciation of the dollar in terms of sterling and the difficulties which are being encountered at the Economic Conference in regard to the temporary stabilisation or world currencies have been outstanding factors in the present unsettlement of markets, and are likely to remain so until the course of events in this connection can be viewed with more clarity".

COCOA.—The cocoa market is still under the influence of exchange fluctuations and speculators are gambling on commodity prices. Stocks in the principal markets still remain comparatively high and actual demand is slow. Fair fermented Accra may be quoted at 25*s.* to 25*s.* 6*d.* and locally $4.50 a fanega is paid.—(*The Cocoa Planters' Association of Trinidad, Limited.*)

* * *

COPRA.—Is quiet and lower with West Indian f.m.s. quoted at £11 10*s.* for July shipment c.i.f. London. — (*West India Committee Circular*, 22nd June, 1933.)

* * *

COFFEE.—*The Times Trade and Engineering Supplement* for June 24th states that Kenya and Costa Rica coffee have continued to sell well but that inferior types trouble the market. Stocks in England at 489,000 cwt. are 100,000 cwt. higher than a year ago.

* * *

TEA.—Latest averages include Ceylon at 10.80*d.*, Indian at 9.64*d.* and Java at 7.30*d.*

* * *

RUBBER:—Quotations for Plantation Sheet have ranged as follows:

	d.
31st May	3 1/2
7th June	3 17/32
14th June	3 3/8
21st June	3 9/32
28th June	3 7/16
5th July	3 3/8
12th July	3 3/4
(13*th July*, 1932)	1 29/32

The market has generally been active with, at times, rather wide fluctuations. According to the *American Questionnaire* the consumption for May was 44,581 tons which is nearly a record having only once been previously exceeded, namely in May, 1929 (49,233 tons). Events in America as far as rubber is concerned continue to move favourably, sales of cars showing a marked increase.

* * *

BANANAS.—Prices are unchanged at: Jamaicas £21 5*s.* per ton delivered London and £21 nearest railway station; Brazilians £19 nearest station.

* * *

LIME PRODUCTS.—*Lime Oil.*—There is still no demand for Handpressed with sellers at 47*s.* 6*d.* Distilled, after some sales at 29*s.* 6*d.*, is firmer on the spot and 32*s.* 6*d.* is now asked. *Lime Juice.* A further small business has been done in Concentrated at £4 10*s.* c.i.f. and probably more could be sold for immediate shipment. Small sales of Raw have been made at 1*s.* 7½*d.* to 2*s.* 3*d.* per gallon.—(*West India Committee Circular*, 22nd June, 1933.)